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SEVEN-INCH HARP GUN-LAUNCHED VERTICAL PROBE SYSTEM: INITIAL DEVELOPMENT

by

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July 1966

U. S. ARMY MATERIEL COMMAND
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

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RDT&E Project No. 1A011001B021

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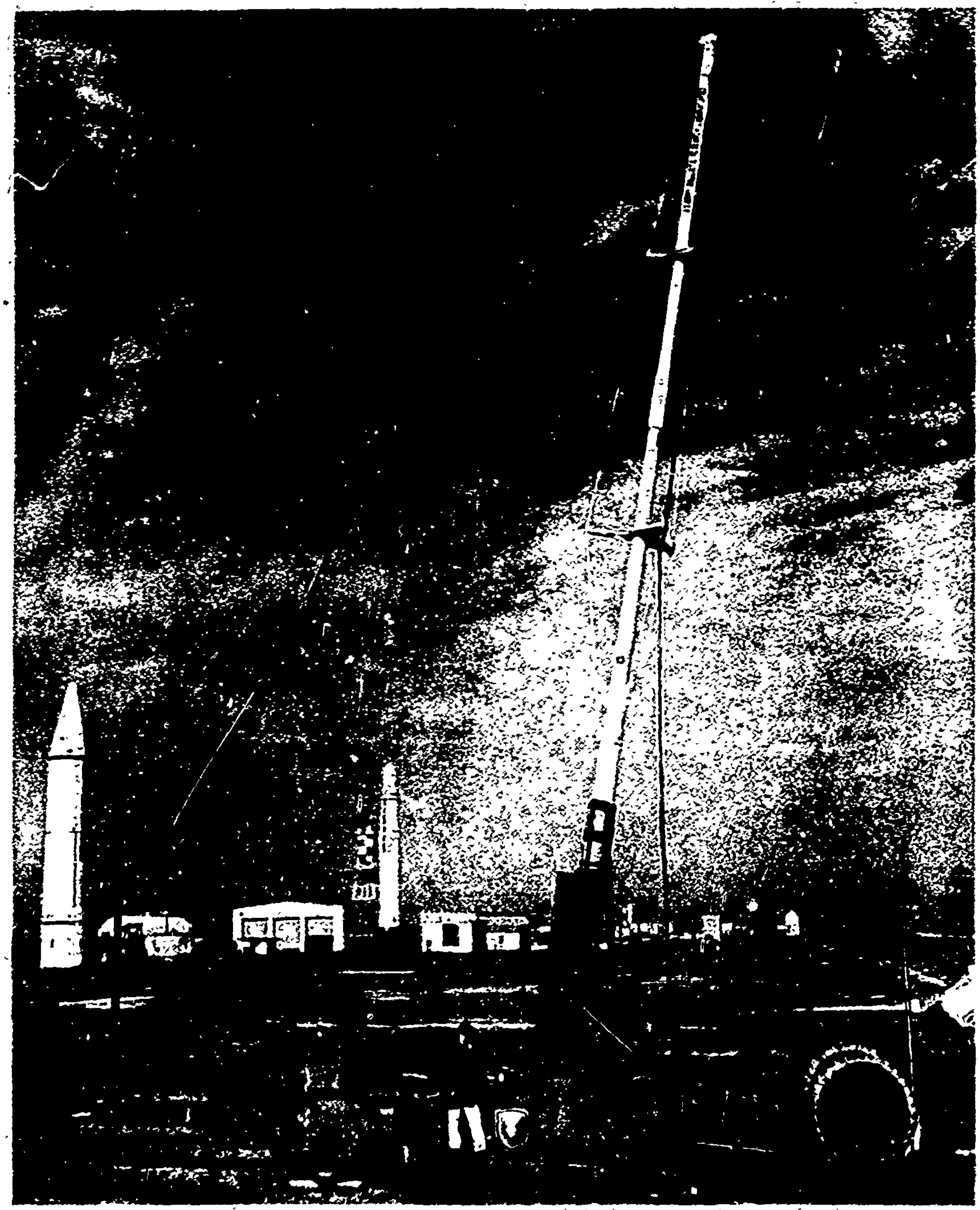

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1770

EDBoyer/LCMacAllister/cr
Aberdeen Proving Ground, Md.
July 1966

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ABSTRACT

The description of an upper atmosphere sounding system, based on a modified 175 mm gun, is given. The 175 mm gun tube is extended and smooth bored, and a T76 mount, modified to permit vertical fire is utilized. The gun is used to launch sub-caliber, fin-stabilized, center-saboted projectiles.

During initial tests, a prototype projectile with a payload volume of fifty cubic inches attained a maximum altitude of 260,000 feet. A smaller version of the projectile, with a potential payload volume of about fifteen cubic inches reached an altitude of 330,000 feet.

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1. INTRODUCTION

In 1959 studies at the Ballistic Research Laboratories (BRL),[1*] Canadian Armament Research and Development Establishment,[2] and the Army Rocket and Guided Missile Agency[3] independently suggested that guns might have a place in the scheme of upper air research and similar areas. The basic advantages to be derived through the use of guns appeared to be: accuracy of placement of probes at altitude, better control of ground impact (compared to unguided rockets), relative immunity to surface wind launch restrictions, and economy. The High Altitude Research Program (HARP) was then initiated to develop gun-projectile systems of various sizes for vertical fire and to utilize these systems to make measurements in the upper atmosphere.[4,5]

In HARP the basic BRL requirement was for a vehicle that could place instrumented packages at altitudes from 200,000 to 350,000 feet and that could be launched from Aberdeen Proving Ground (APG), Maryland or other sites where range safety precludes the use of sounding rockets. In Reference 1 it is indicated that, in order to achieve these altitudes and package requirements, a high performance, sub-caliber, fin-stabilized projectile would have to be employed, together with a long gun having a bore size between 6 to 8 inches. The only high performance gun that seemed to fit in this category at that time (1961) was the then new 175 mm, M113 gun. The tube for this gun had just been developed and, unfortunately, a surplus of new tubes or a quantity of worn-out tubes would not become available for several years. This lag time prompted a decision to go ahead with a smaller 5-inch prototype system based on the 120 mm, T123 gun, in order to develop the package and to demonstrate the feasibility of a gun-probe system. It was believed that this approach would materially shorten the time scale of the future 7-inch development phase and the smaller system might have a utility of its own as a sub-200,000 foot meterorological probe.

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*Superscript numbers denote reference which may be found on page 66.

In the period 1961 to 1964, the tests of the 5-inch system furnished a substantial foundation for the 7-inch system design and test plans. In particular the tests provided:

a. General feasibility and impact accuracy[6,7,8]

b. Aerodynamics and physical design parameters for the projectile[7]

c. Package development[8,9,10,11,12]

d. Indication of special problem areas:

   1. Fin section to boom connection problems

   2. Damage to aluminum fin sections due to gun gas erosion, in-tube balloting, and sabot discard

   3. Retention of the nose cone.*

In early 1963, the first scrap materiel became available in an amount sufficient to manufacture two extended 7-inch tubes of a compromise design. Watervliet Arsenal had a design based on maximum utilization of two M113 tubes to fabricate a 7-inch gun. The two M113 tubes that were available had been damaged in manufacture, and about 6 feet of the muzzle end of the tubes would have to be removed to eliminate the defects. Two worn-out tubes were available for use as extensions to the main tubes, but these were from an early preproduction design, and the steel was of a lower quality than that in the M113 tubes. The use of the available material would permit a 9 month gain in time, and Watervliet was requested to modify their design for the purpose of the manufacture of the Serial No. 1 and 2 tubes only. Tubes with higher serial numbers were to be produced according to the original design, at such future time when proper material became available. This manufacture and use of two tubes of sub-design performance does confuse the description of some of the early planning and testing, since some things, done only because these tubes were used did not contribute to the final development based on the latter tubes.

The nose joint had to be strong enough to survive the 50,000 G launch load and the subsequent elastic rebound, and yet weak enough to permit ejection of the package without damage. Eventually a double locking system was devised (Section 3.4).

The initial procurements of projectiles were in small numbers, a total of only 35 were available over a 9-month test period. The shortage of projectiles made it necessary to design many tests as multi-purpose. In the period from May 1964 to March 1965, three horizontal test series and two vertical test series were carried out. These tests together with the original and revised development plans are reported here.

2. DESCRIPTION OF SYSTEM

A general description of the system is given below; more detailed descriptions of the components are given in later sub-sections.

A smooth-bore, 7-inch gun tube, 55 feet long, is used to launch sub-caliber. centrally saboted, fin-stabilized projectiles. The tube is mounted in a 175 mm, T76 field carriage which is modified to permit launch angles up to 88 degrees. The long flexible tube is braced with a three rod trussing system to reduce flexure and droop; the truss recoils with the tube. A separately loaded, bagged, propellant charge is used. Payload volumes and the acceleration environment depend on the particular projectile design and the devised maximum altitude; current characteristics are in the following ranges.

a. Payload volumes from 35 to 50 cubic inches.
b. Launch velocities from 4000 to 6200 feet per second.
c. Launch weights of 45 to 80 pounds.
d. Launch accelerations from 25,000 to 55,000 G's.
e. Maximum altitudes from 250,000 to 350,000 feet.

2.1 Projectiles

The projectile, as loaded into the gun, consists of three functional parts; the flight projectile, the metal sabot, and the plastic sealing parts, Figure 1. The projectile is supported in the tube by the sabot and the contact of the fin tips on the bore of the tube.* The gun gas

**Recent practice has been to keep the fins clear of the bore and provide support by the sabot alone.*

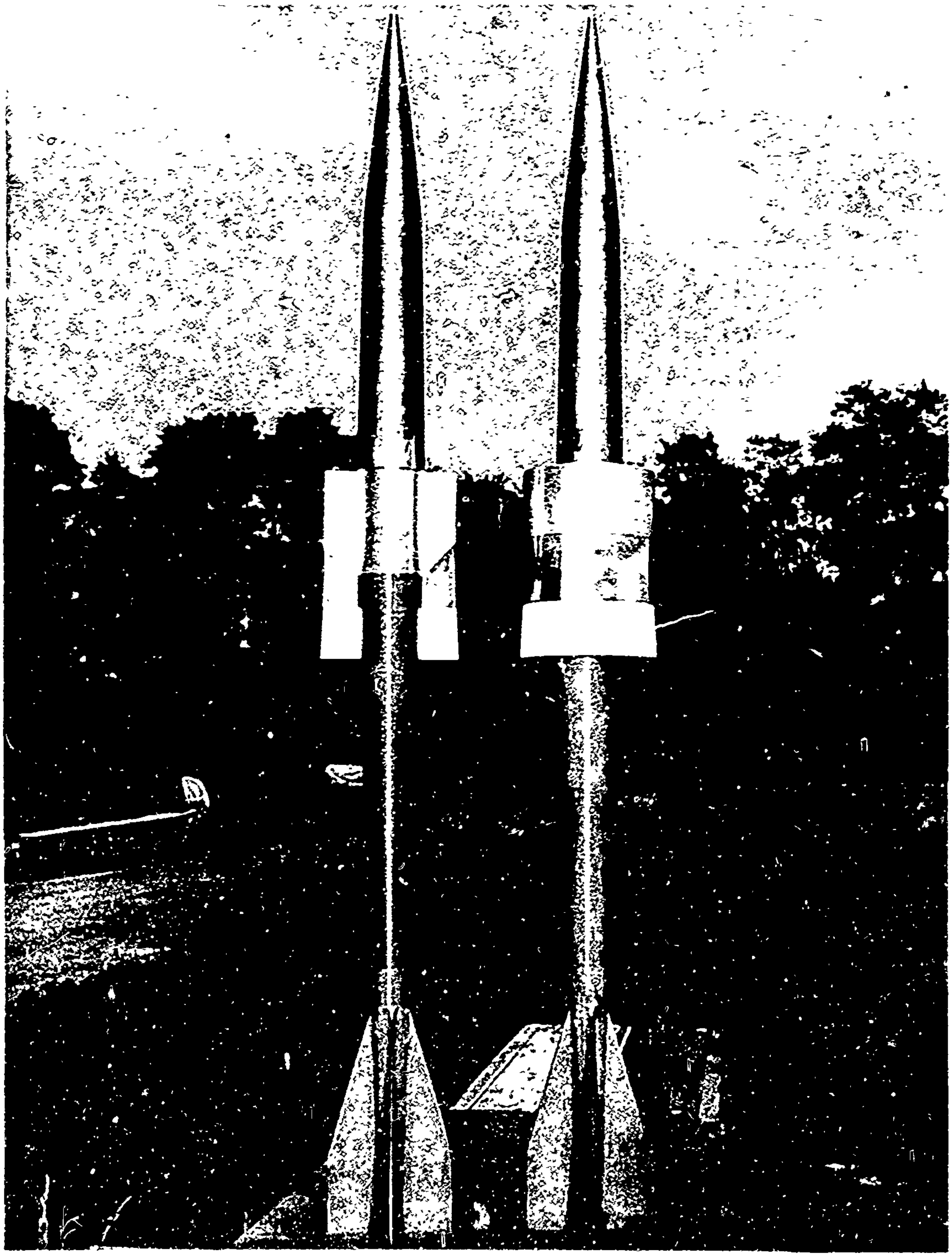

FIGURE 1. 7-1 PROJECTILE WITH SABOT

pressure is applied directly to the flight projectile at the aft part of the flight projectile which is in contact with the gun gases, and is indirectly transmitted through the plastic seals to the metal sabot and thence to the flight projectile. The plastic seals are attached behind the metal sabot in order to provide a gas seal. The beveled interface between the metal and plastic parts promotes automatic closure of gas passages that might otherwise be opened due to wear in passage. The plastic parts serve as the prime gas seal and also provide additional support to the projectile. As the vehicle leaves the muzzle, the gas pressure squirts the plastic parts forward and outward over the sloped aft surfaces of the metal sabot; during this time the metal parts are still locked to the model. After ejection of the plastic parts, the ram air load on the metal parts forces them aft; this action unlocks the sabot from the threads on the projectile and causes the parts to be discarded aft and outward. Figure 2 shows this sequence. Note that the current sabot is designed to give a minimum dispersion of sabot fragments on the ground - it is possible to achieve a more rapid sabot separation by omitting this requirement. The use of saboting adds a weight penalty of about 16-1/2 pounds; projectiles with in-flight weights of 40 to 75 pounds can be used.

Currently one type of projectile (7-0) has been tested; another type (7-1), which is a slight modification, is being procured; a prototype of a third (7-2) has had very limited tests; and a fourth design (7-3) has been outlined. These various projectile designs can be briefly described as follows:

PROJECTILE	DESCRIPTION
7-0	A general purpose projectile of 7-inch fin span, 4-inch major diameter, a length of 63.5 inches, and a nominal maximum usable volume of about 50 cubic inches.
7-1	A general purpose projectile with the same capacity as 7-0, but a diameter of 3.6 inches; the fin span and length remain the same as in the 7-0.

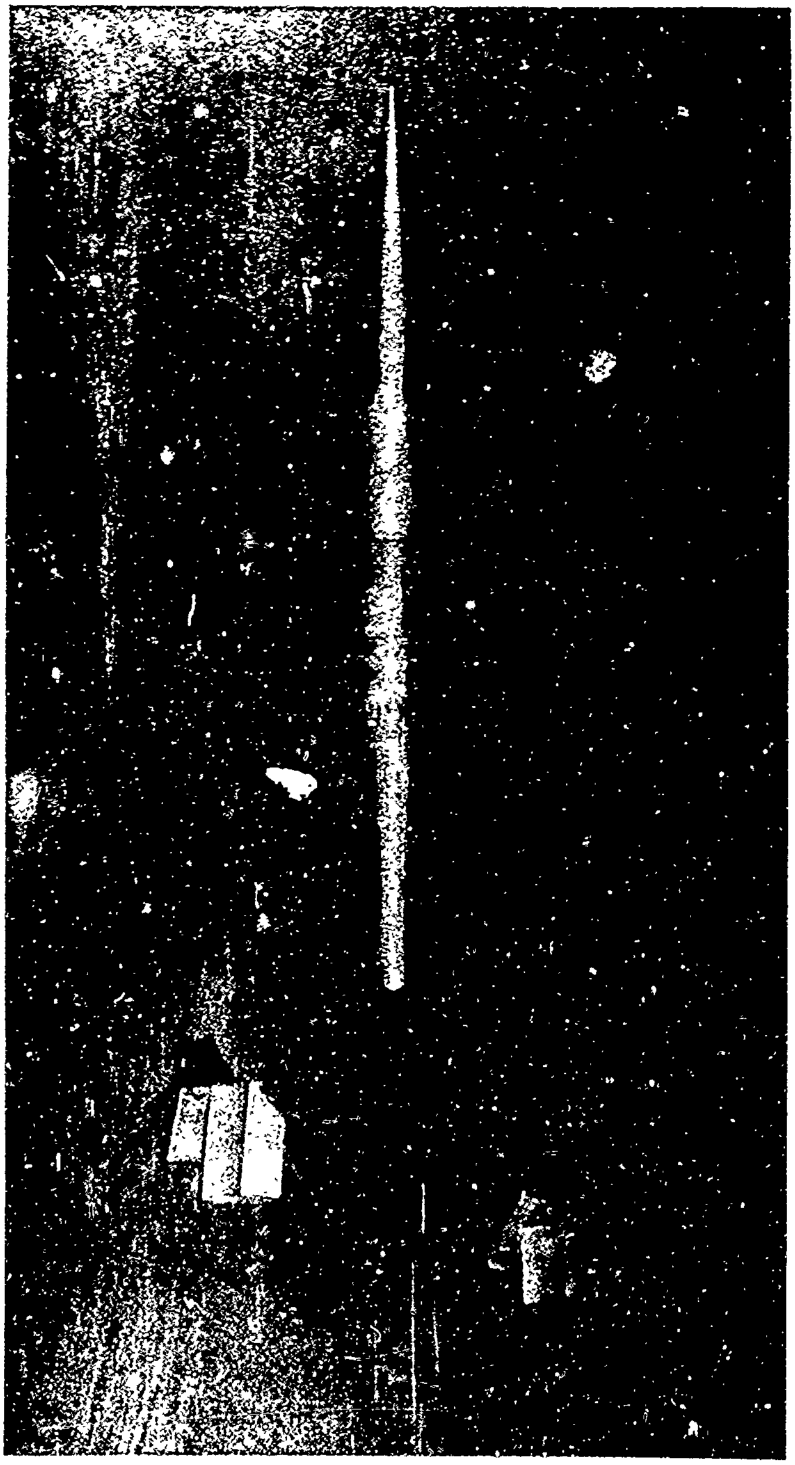

FIGURE 2. SABOT SEPARATION

PROJECTILE	DESCRIPTION
7-2	A special purpose high performance projectile with a payload volume of 35 cubic inches, a fin span of 7 inches, a body diameter of 3 inches, and a length of 55.4 inches.
7-3	A special purpose projectile with "high" capacity but lower altitude performance.

Upon completion of projectile development, it is hoped to have a basic family of three projectiles. Future payload testing and requirements will determine the final configurations of payloads.

The altitude capability of the various projectiles as a function of velocity is shown in Figure 3. The curve for the 7-3 vehicle is based on estimates of probable flight weight and drag. The curves are dashed in the region beyond the current estimate of the highest velocity expected with the currently developed system.

2.1.1 7-0 General Purpose Projectile. A general arrangement of the projectile is shown in Figure 4. The center of mass for the loaded flight projectile should be forward of 36 inches from the base of the projectile. The forward body is of steel having at least 120,000 psi yield point; the after body, fins and sabot crown are of 7075 ST6 aluminum alloy. The fins require a hard anodized finish for thermal protection. To meet the ballistic requirements of different payloads, either a steel or an aluminum nose cone can be employed.

The forward payload cavity can be enlarged to a maximum diameter of 2.5 inches to satify some payload requirements, and, similarly, the after body compartment can be enlarged to a maximum diameter of 1.8 inches. Such changes require a recheck of the stress levels at the nose-fore body interface, the base of the forward payload cavity, and the base of the aft payload cavity for the particular conditions of the planned mission, to see if the stress levels are within acceptable limits. For tests where ejection of a solid package from the projectile is required at altitude, the space shown in the nose cone and the one inch diameter

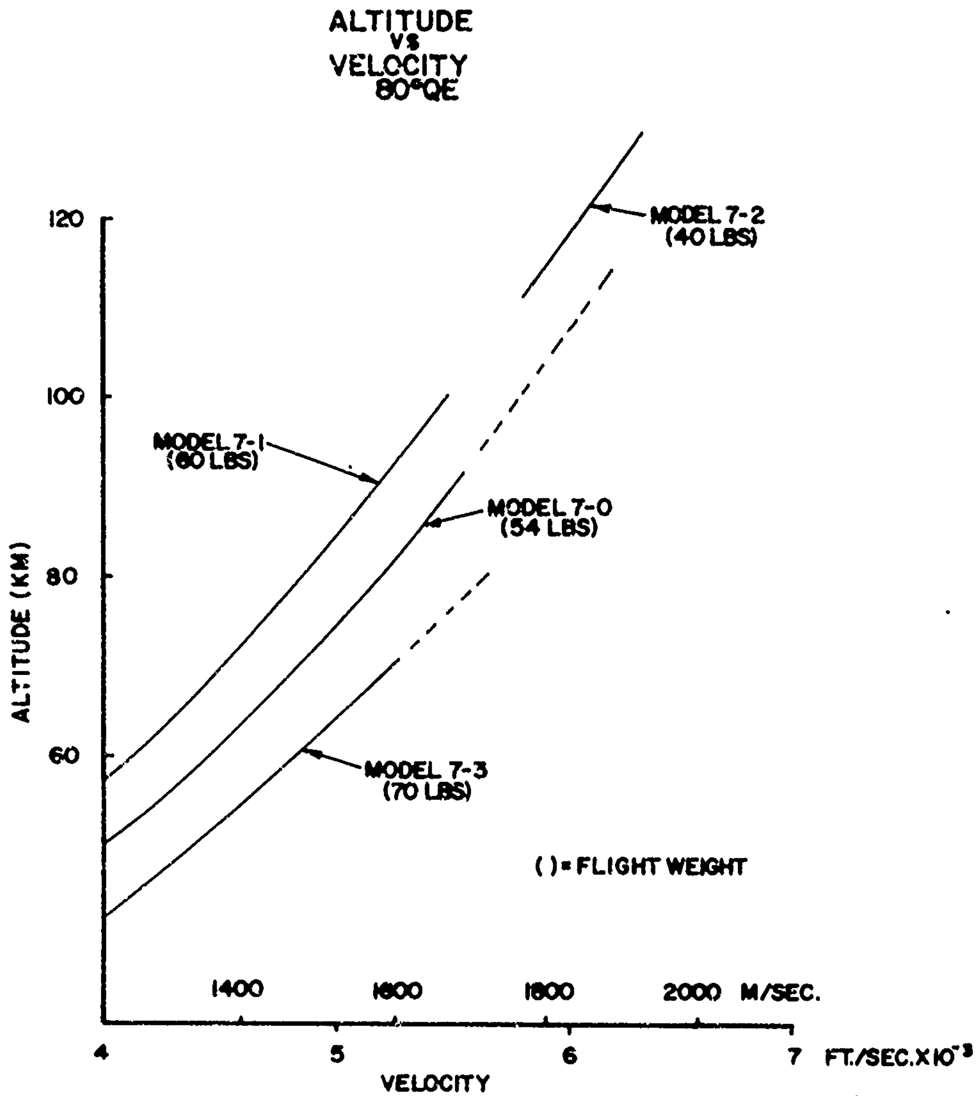

FIGURE 3. PROJECTILE ALTITUDE AS A FUNCTION OF VELOCITY

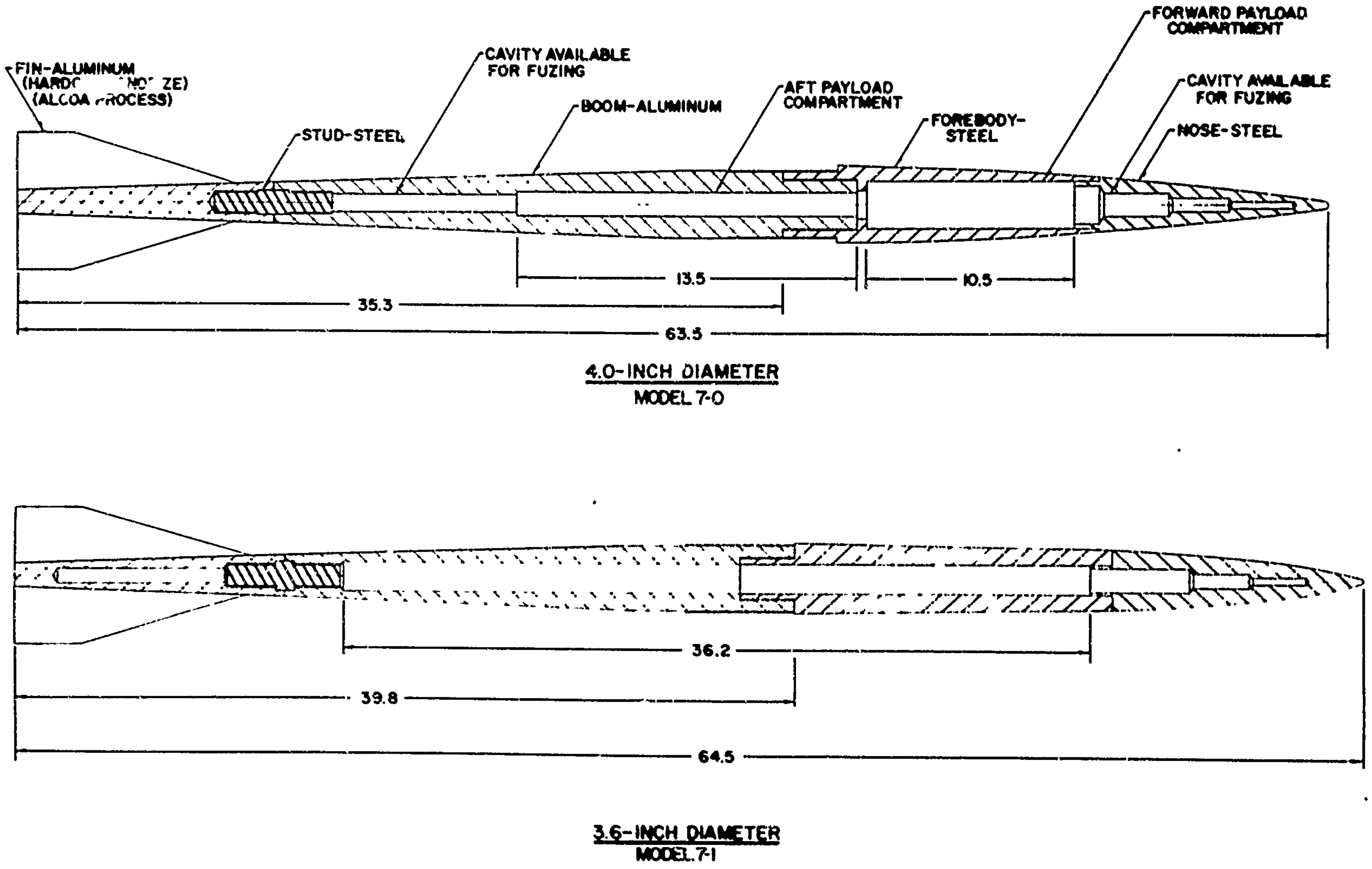

FIGURE 4. 7-INCH VERTICAL PROBE GENERAL PURPOSE PROJECTILES

cavity just ahead of the tail will normally be required for fuzing.. These spaces can be considered as payload volume if ejection is not required.

2.1.2 7-1 General Purpose Projectile*. The 7-1 projectile is similar to the 7-0 projectile design, but has potentially higher performance with about the same payload capacity. The smaller diameter of the 7-1, Figure 4, is made possible by the use of 180,000 psi yield steel in the body. Figure 5 is a cut away view of the 7-1 model.

2.1.3 7-2 Special Purpose Projectile. The 7-2 projectile, Figure 6, has the maximum altitude performance with about the lowest acceptable payload volume. A prototype has been tested. High strength steel is used in the nose and forward body, and high strength aluminum alloy in the aft sections. Further testing may indicate that the fin blades be made of steel. High impact strength nylon is used for the sabot base segments rather than the Lexan used in the lower performance projectiles. A package cavity of 1-1/2 inch diameter and 20 inches long is available. The center of mass of the loaded projectile should be forward of 28 inches from the base.

2.1.4 7-3 High Capacity Projectile. The high capacity projectile 7-3 is only a concept of a projectile which would attempt to fill a possible need for a maximum volume, ejectable payload with a maximum altitude requirement of 200,000 feet. As proposed, the projectile is all steel with a cylindrical body, an ogival nose, and a maximum body diameter of 4.5 to 5 inches; see Figure 6. A fuze would be in the noze cavity with ejection of the payload rearward.

2.2 Tubes

Three types of tubes for the 7-inch system are either in use or in manufacture. The first type is represented by Serial No. 1 and Serial No. 2 tubes. The main tube of this type is the damaged M113 tube which was shortened by 6 feet; a separate collar is used to attach the extension,

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This projectile has recently attained an altitude of 300,000 feet.

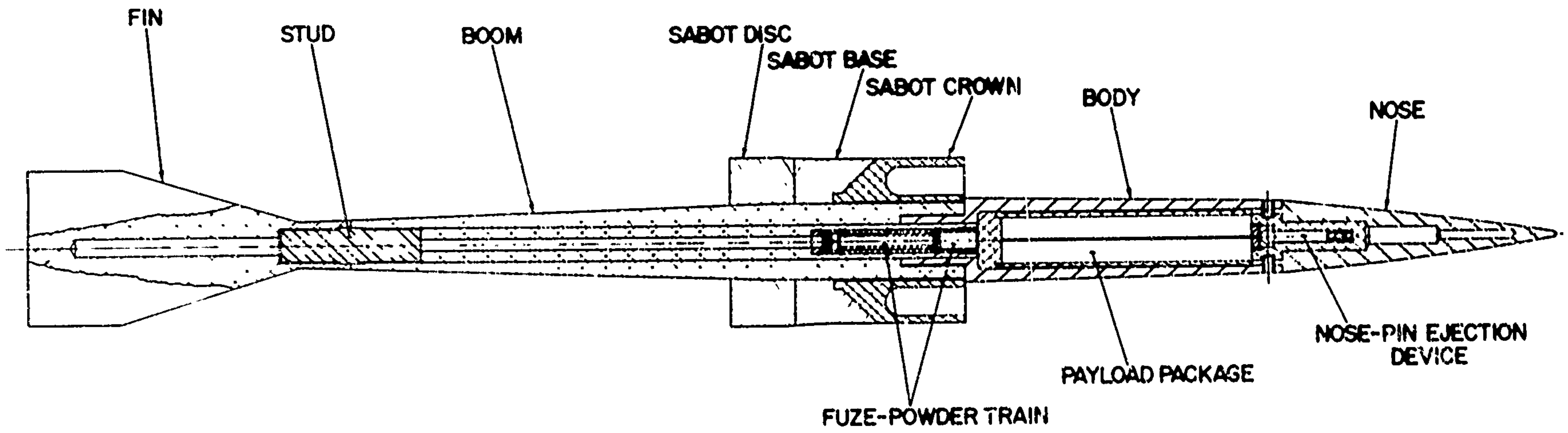


FIGURE 5. HARP 7-1 PROBE PROJECTILE

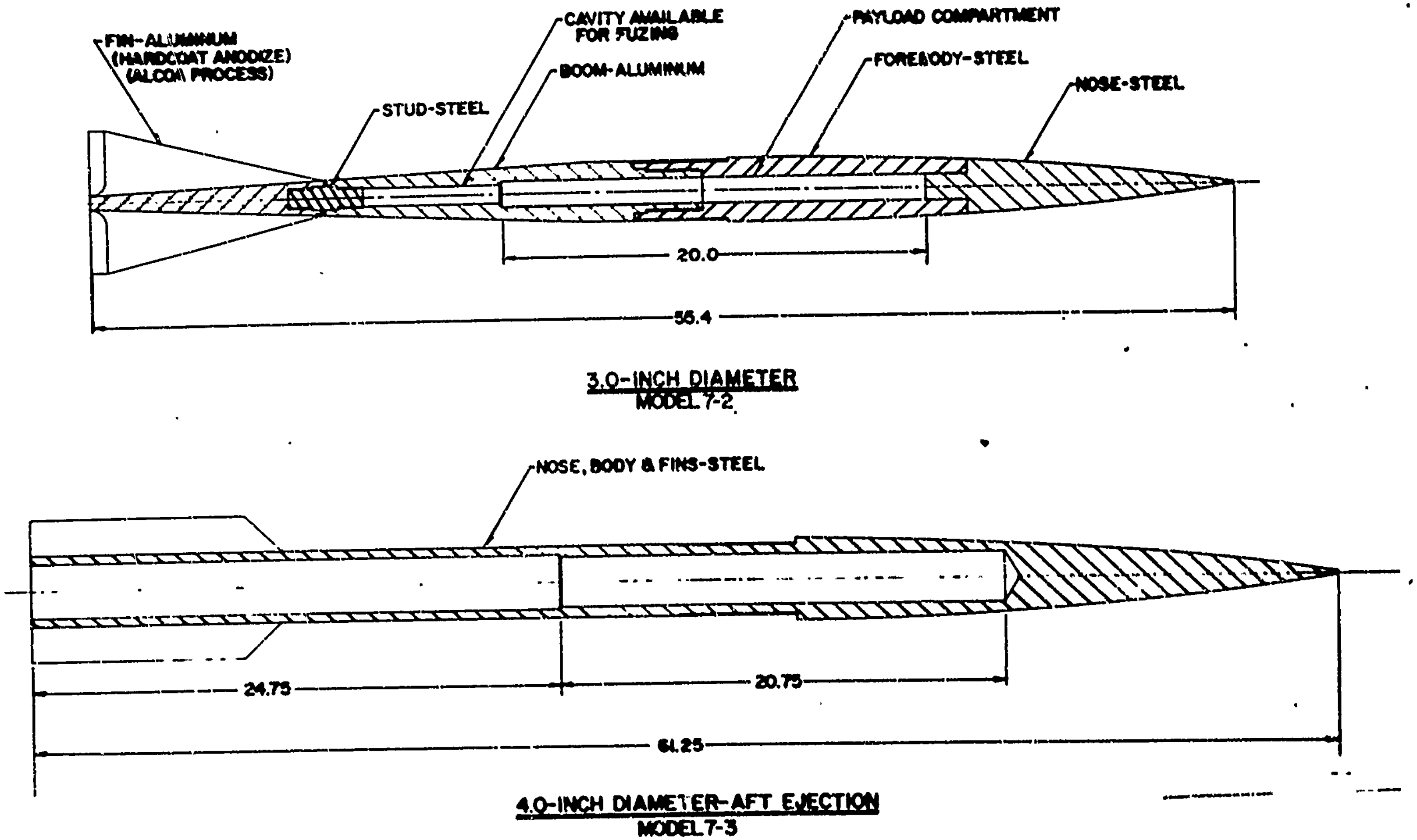


FIGURE 6. 7-INCH VERTICAL PROBE SPECIAL PURPOSE PROJECTILES

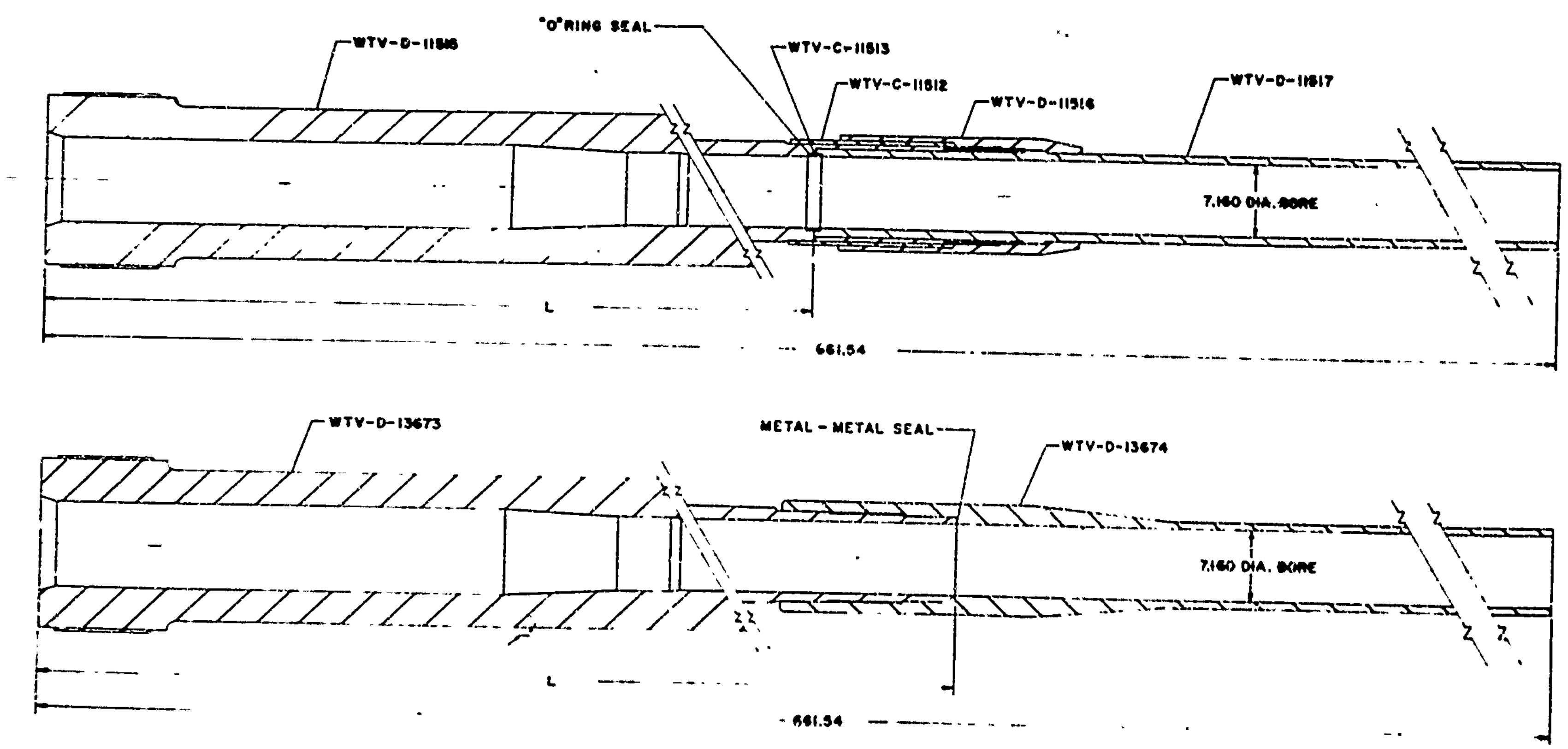
made of one of worn-out tubes, to the main tube; a floating steel ring with an "O"-ring is used as an internal gas seal. The steel used in the extension has lower mechanical strength than that used in the main tube. The second type of tube (logically, but not chronologically) is represented by modifying the No. 1 and No. 2 tubes by using a full-strength extension with an integral threaded attachment to the main tube with a metal-to-metal internal seal (the main tube being still 6 feet short). The third type of tube is represented by tubes Serial No. 3 and higher; the main tube is full length and the extension and connections are similar to the second type. Both sections are made from M113 tube material. Results from tests using the second type of tubes are not included in this report. Diagrams and characteristics of the tubes are contained in Figure 7.

In the testing, some horizontal tests were carried out with the bare tube supported by external means; i.e., various rests over which the tube slid in recoil, held the tube level at several points. Other horizontal tests were carried out with the tube supported in its own truss system. The vertical tests were carried out with the truss system. The bare tube support case is shown in Figure 8. There is no indication that the various support systems influence the results given.

2.3 Mounts

There were two types of mounts used in the initial testing: the Aberdeen Proving Ground (APG) universal mount, with the tube separately supported, and the modified T76 field mount, with the tube supported by a truss-rod system. Both mounts posed test limitations in horizontal fire. Only the T76 mount, which is used in vertical fire, will be described in any detail (frontispiece).

During the development of the 175 mm gun, two experimental T76 field carriages were made for the 175 mm, T145 tube. These two carriages were modified to accept the 7-inch probe gun and to permit elevation to 88°. The T76[13] has a double recoil system: the gun tube recoils with respect to the top carriage (36-inch maximum) and the top carriage recoils with respect to the bottom carriage (55-inches maximum). This eliminates



TYPE	TUBE NO.	METAL SOURCE EXTENSION	SEAL	L
I	1, 2	T 146	"O" RING	381"
II	1 MOD A, 2 MOD A	M 113	METAL	381"
III	3, 4, etc.	M 113	METAL	413"

FIGURE 7. 7-INCH PROBE TUBES

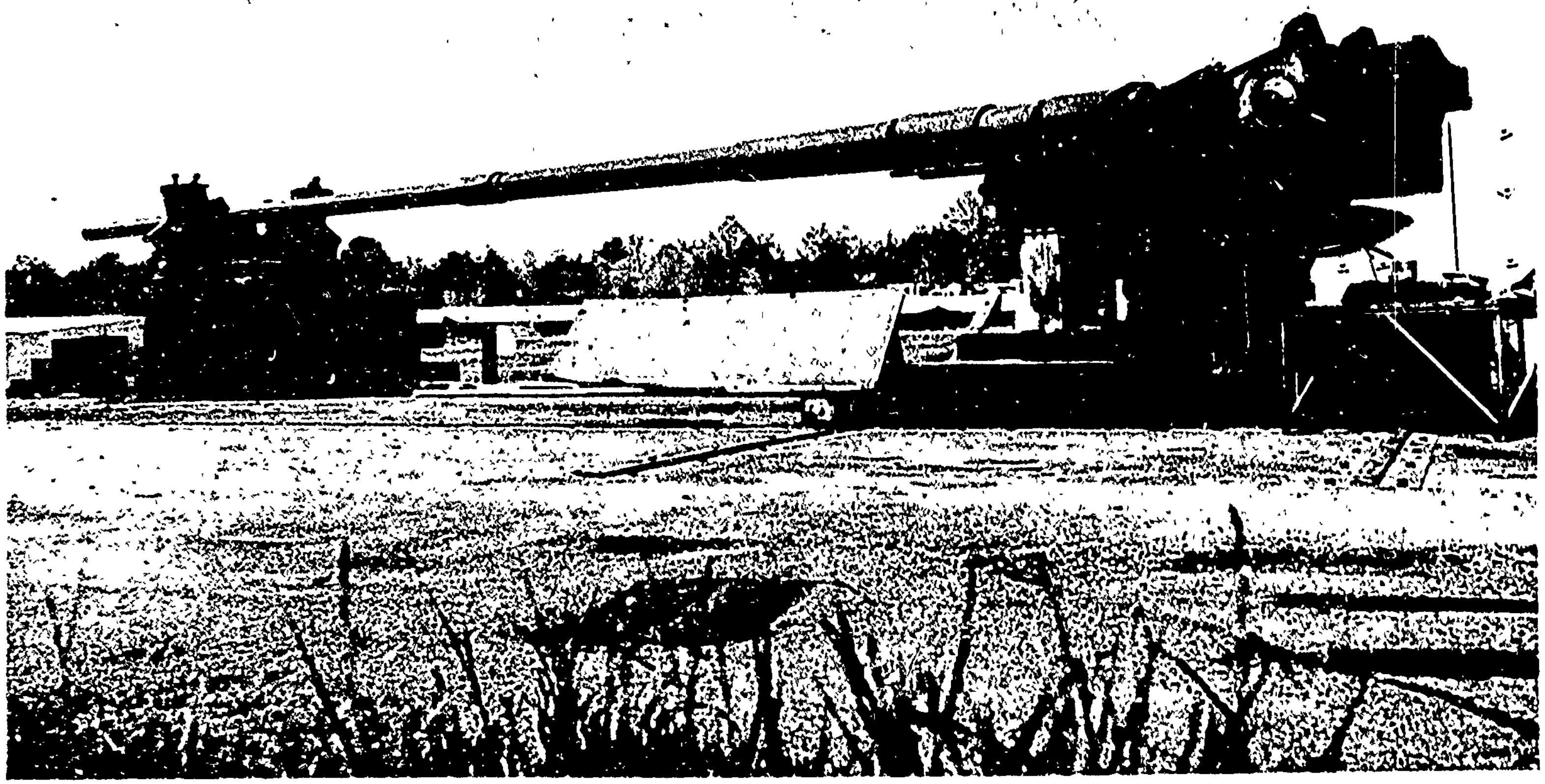


FIGURE 8. TUBE IN UNIVERSAL MOUNT WITH EXTERNAL SUPPORT

the need for a dug-in emplacement. The recoil-recuperator system is of the nitrogen-hydraulic type, and uses two separate buffers to stop the final counter-recoil motion. In the firing position, the carriage rests on a circular front float and a rectangular rear float. The mount is traversed by rotating on the front float. For transport, a two-wheel bogie is lowered at the muzzle end of the carriage, and a two wheeled limber is attached to the breech end of the carriage, Figure 9.

Overall physical characteristics of the T76 with the probe tube are listed in Table I. The modifications for use in vertical fire included adding a section to the elevation rack, increasing the stroke of the hydraulic elevating rams, removal of some redundant sub-systems to give recoil clearance, replacing the short-stroke implusive loading ram with a long stroke hydraulic ram, and lead ballast to compensate for the longer tube.

In horizontal fire, the APG universal mount approached maximum recoil limits at about 70 percent of peak gun performance, and could not elevate or traverse the long tube. The double recoil of the T76 mount was adequate in horizontal tests only to about 80 percent of performance due to secondary recoil limits (actually, the mount slid on wet soil and alleviated the problem, but a sliding "recoil" of 12 feet did not promote any enthusiasm for continuing firing tests). In vertical tests the T76 mount handled the peak loads with no limitations.

Since there were only two T76 mounts, Rock Island Arsenal was asked to investigate the feasibility of utilizing other mounts, specifically, the 280 mm gun carriage and the 8-inch Howitzer field carriage. It was determined[14] that the 280 mm could be modified, would have large safety margins, but would be expensive to modify and cumbersome to use and transport. The 8-inch mount could be modified also, would have only small safety margins, but would be much handier in use and transport than the 280 mm mount. It is planned to produce a prototype of the 8-inch mount modification for testing.

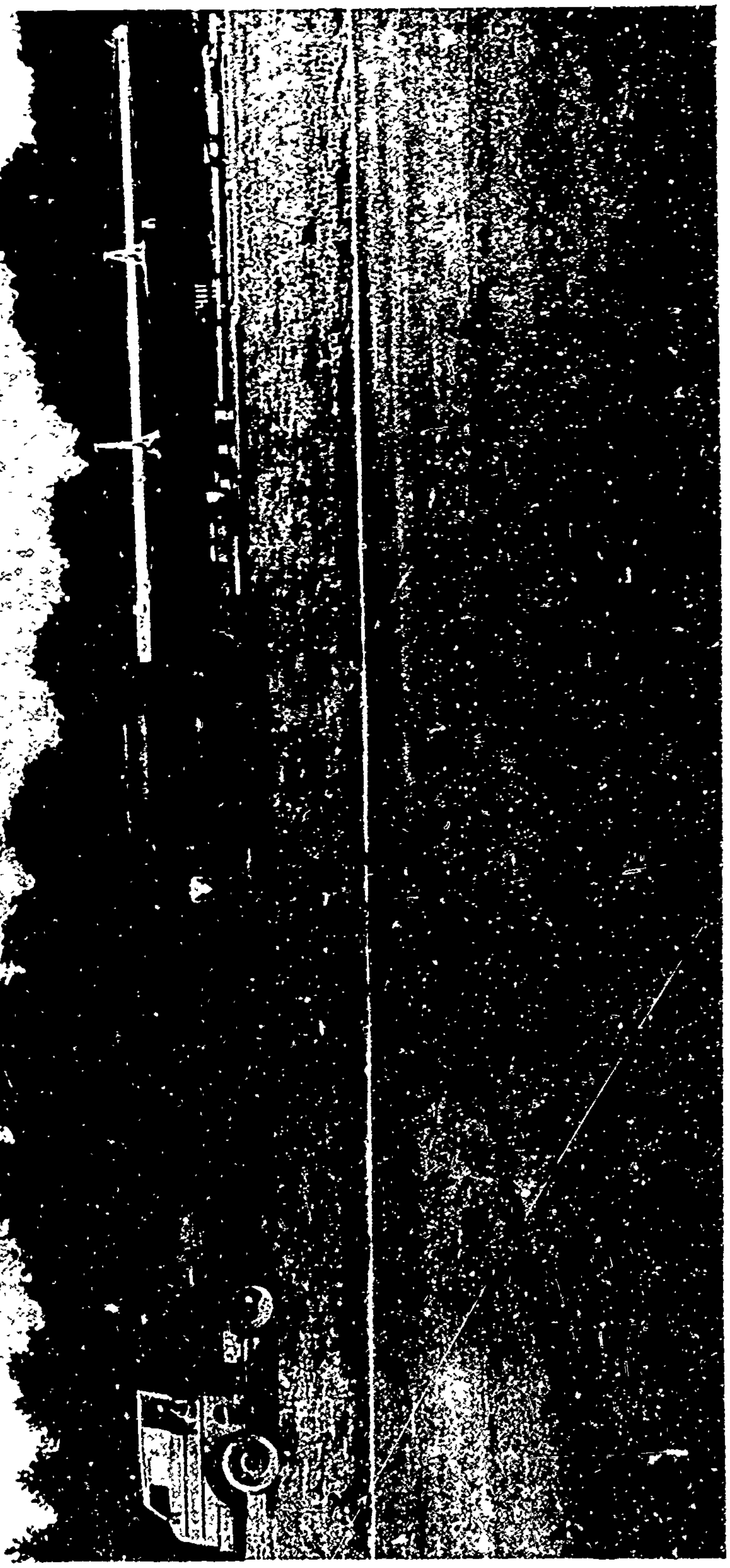


FIGURE 9. T76 MOUNT IN TOWING POSITION

TABLE I

APPROXIMATE PHYSICAL CHARACTERISTICS OF T76 MOUNT WITH PROBE TUBE

1.	Total Weight of Gun and Carriage	Pounds
	a. Transport condition	50,000
	b. Firing condition	45,000
	c. Load per wheel	12,500
2.	Overall Length	Feet
	a. Traveling	72.5
	b. Firing	66.5
3.	Overall Height of Carriage	Feet
	a. Traveling	13
	b. Firing	10
4.	Overall Width	10.5 Feet
5.	Ground Clearance	20 Inches

2.4 Propellant-Ignition System

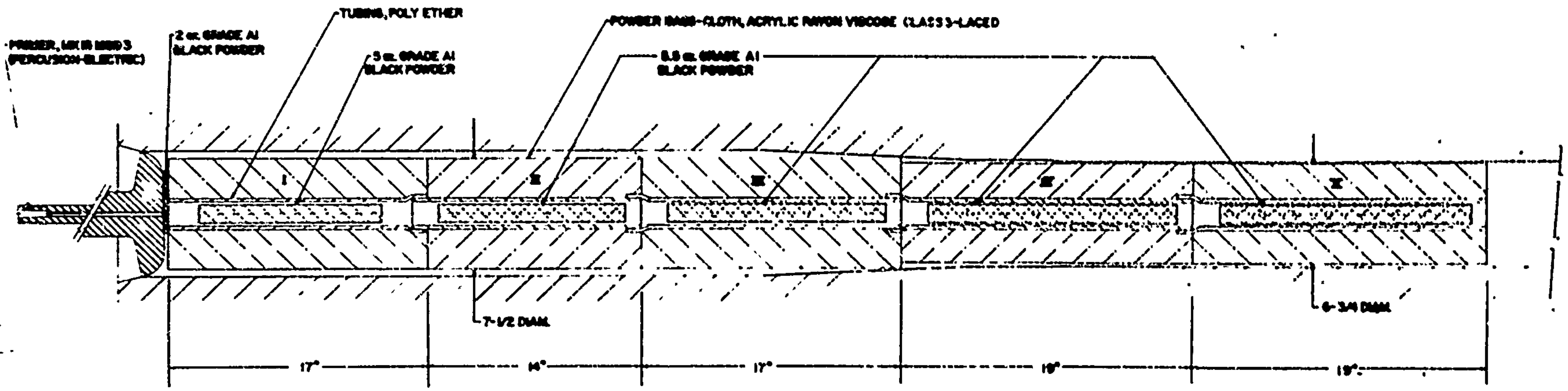
The propellant-ignition system is illustrated in Figure 10. Although this system provided satisfactory performance, it is not considered to be optimum. The system is considered safe for use in firings which are conducted under proving ground safety conditions.

M17MP propellant was used for all charges. For the 50-pound projectiles, a dual-granulation charge which contained a mixture of 0.079-inch and 0.114-inch webs was used in the No. 3 and No. 4 gun tubes. Since the extensions for the No. 1 and No. 2 tubes are weaker than those of the other tubes, it was necessary to use different propellant webs to fire the light projectiles from these tubes. A dual-granulation charge which contained a mixture of 0.052-inch and 0.079-inch webs was adequate for this purpose. The smaller webs produce a faster burning charge and consequently, a lower downtube pressure. A single-granulation charge, with an 0.114-inch web, was used to fire the 80-pound projectile from all tubes. For all charges, the propellant was loaded into bags of the type used in the standard M86 charge of the 175 mm Gun, M113. A typical bag contains about 20 pounds of propellant.

The perforated, polyether igniter tube, the base pad, and the black powder igniter bags of the 175 mm Gun system are used in the ignition system. A MK 15, MOD 3 primer is used for initiation.

2.5 Loading System

The projectiles are prepared, in the anticipated number required for a test series, usually 20 to 30 at a time. The major diameters of the aluminum sabot and the projectile are machined to 0.004-inch under the bore diameter of the tube. The front portion of the lexan sabot is turned to this same diameter. The last 1.5 inches of the lexan sabot have a 3° (included angle) ramp. This ramp will serve as the forcing and gas sealing member of the sabot. Finally, the polyethylene discs are turned to this same major diameter. In assembling these parts of the sabot to the projectile, a liberal amount of silicon grease is applied to all mating surfaces. The surfaces which ride on the bore of the tube are coated with Molylube or grease emulsion.



MIXED CHARGE - 80% .079 WEB + 20% .052 WEB

INCREMENTS	I	II	III	IV	TOTAL CHARGE
WEB SIZE	.079	MIX	MIX	MIX	LBS.
	WEIGHT				
	22	20	23		65
	20	20	20	15	75
	20	20	20	18	78
	20	20	20	20	80
	22	20	21	22	85

MIXED CHARGE - 80% .079 (or .078 WEB) + 20% .114 WEB

INCREMENTS	I	II	III	IV	V	TOTAL CHARGE
WEB SIZE	MIX	MIX	MIX	MIX	MIX	LBS.
	WEIGHT					
	20	20	20	20		80
	20	19	19	16	16	90
	20	20	20	20	18	98
	20	20	20	20	20	100
	25	20	20	20	19	104

CHARGE - 100% .114 WEB

INCREMENTS	I	II	III	IV	V	TOTAL CHARGE
WEB SIZE	.114	.114	.114	.114	.114	LBS.
	WEIGHT					
	20	20	20	20		80
	27	19	19	16	17	99
	24	20	20	[illegible]	[illegible]	100
	23	[illegible]	20	20	20	110
	[illegible]	25	20	[illegible]	20	116 **

* INDIVIDUAL ROUND BREAKDOWN IS GIVEN IN TABLE - OVERALL LENGTHS MAY VARY WITH TOTAL CHARGE WEIGHT

** A INCREMENT VI OF 6 LBS. IS ADDED

A 19-INCH PIECE OF ADDITIVE IS WRAPPED AROUND INCREMENT IV

FIGURE 10. BASIC CHARGE CONSTRUCTION - 175mm M86E1 IGNITION SYSTEM

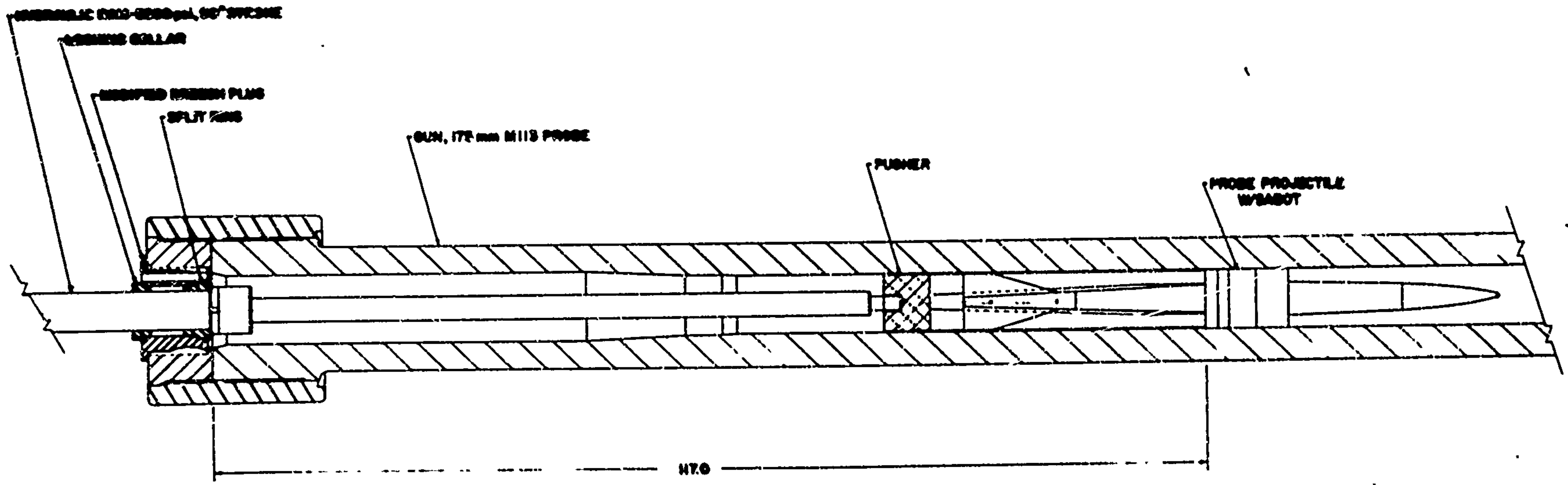


FIGURE 11. PROBE PROJECTILE LOADING MECHANISM

The projectile-sabot unit is inserted into the gun with the aid of a loading fixture and a hydraulic jack, Figure 11. The fixture fits up over the fins and boom, bears on the back face of the sabot and locks to the ram of the hydraulic jack. The projectile, fixture and jack are moved forward until the sabot is about to enter the forcing cone; the jack is then locked to the breech block and is used to push the projectile to the desired loading distance (about 117 inches from the rear face of the tube). A peak force of about 10 to 30 tons is used; no particular importance is ascribed to this value. However, the frictional force exerted against the gun tube by the sabot plastic, as evidenced by the ram load, has to be high enough to retain the projectile in place as the gun is elevated and even against the shock of another gun firing in close proximity. After the projectile is seated, the ram and fixture are withdrawn and the charge (weighing about 100 pounds and 90 inches long) is loaded using a non-sparking support tray, Figure 12.

3. SYSTEM TESTS

The scarcity of projectiles led to the necessity of using each shot for as many purposes as possible: i.e., one shot might be part of an interior ballistic series, a metal parts test for fin strength, and a test of a new nose-cone retention system. The recoil limitations encountered in horizontal firing meant that the high pressure phases of the interior ballistic tests had to be done in vertical firings where flight performance and instrument package functioning were the primary goals. An attempt to describe the tests on a chronological basis would lead to confusion. The most logical approach is to consider each test series as a separate entity, as if it had been fired only for the purpose under discussion. Thus, many shots are re-tabled and rediscussed.

The horizontal tests, utilizing proof slugs and probe vehicles, were conducted at APG. A total of 28 firings were made over the period from May 1964 to February 1965. The vertical tests were conducted at the Wallops Island launch site of National Aeronautics and Space Administration (NASA) with the assistance of their personnel. The vertical tests encompassed 22 launchings from December 1964 to March 1965.

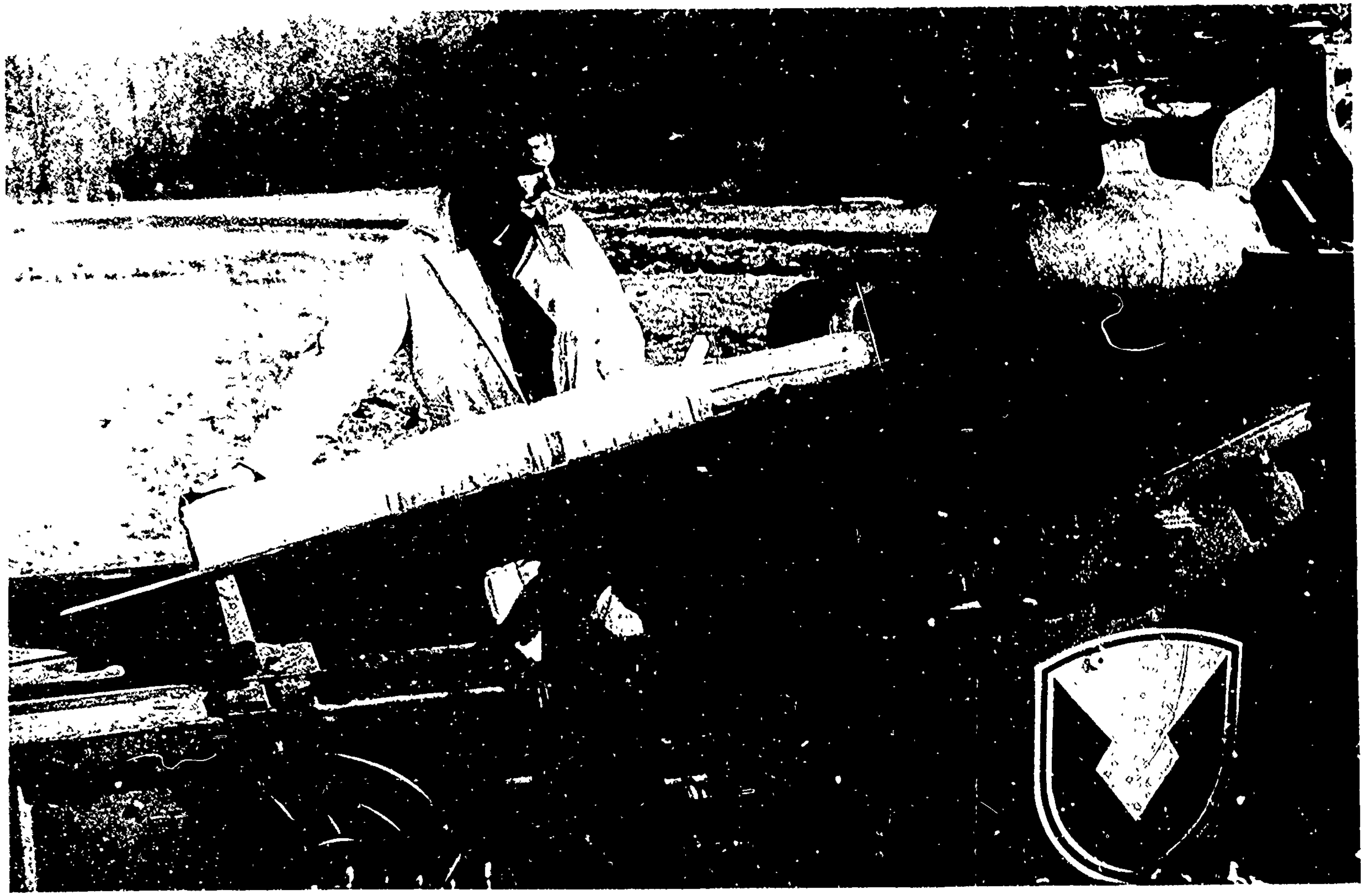


FIGURE 12. POWDER LOADING TRAY

The basic data, such as velocity, propellant gas pressure, etc., were obtained by various methods depending on the test site and availability of equipment. In general, the horizontal tests utilized high speed photography (smear photographs) for determining the state of the projectile and the projectile velocity ahead of the gun. Velocities measured by in-bore probes used with electronic counters provided the prime muzzle velocity source. Chamber pressure was determined by utilizing a strain gauge technique[16] and M11 copper crusher gauges as a backup. At Wallops Island the in-bore velocity probes and doppler radar were used for velocity measurements; the M11 copper gauges and the strain gauge technique for pressure measurements; smear photography for determining state of the projectile; and the tracking radar available (MOD II, FPS-16, MPS-19, FPQ6, SPANDAR)[17] for tracking the projectile and determining flight apogee.

3.1 Projectile Structural Performance

The basic 7-0 projectile test data are given in Table II. The first firing was made at 31,000 psi gun pressure, the sabot and projectile components remained intact (Round 6902). The second firing was made at a gun pressure of 59,000 psi and inadequate obturation caused sabot failure (Round 6907, Figure 13). The obturation was improved by extending the length of the polyethylene seal as shown in Figure 14. The next round, (6909) was fired at 53,000 psi. This vehicle (and the previous ones) employed an aluminum stud to hold on the fin assembly, Figure 5, and four 7/32-inch roll pins to hold on the nose. The expected retention problems developed, Figure 15. The next three projectiles each had a steel tail-stud and 5/8-inch roll pins in the nose. The tail unit remained intact, the nose was retained, but was loosened as shown on Round 7153 in Figure 16. All succeeding firings utilized projectile models with a steel tail-stud and a nose retention system which had a fuzing system to blow out two heavy pins after launch. This system is shown in Figure 17. Four pins were used to retain the nose, two 5/8-inch

TABLE II

METAL PARTS AND FUZING - 7-0 MODELS

Round	QE Degrees	Package	True Pressure PSI	Ejection Fuzing (Sec.)	Ejection Time (Sec.)	Nose Retention Pins	Condition of Model Metal Parts after Launch	Photos. Given (Fig.)
6902[1,2]	0	Inert	31,000			4 ea 1/8 R	OK	13
6907[1,2]	0	Inert	59,200			4 ea 1/8 R	Sabot and nose failure	13
6909[1]	0	Inert	52,600			4 ea 1/32 R	Fin stud and nose failure	15
6916	0	Inert	51,700			4 ea 5/16 R	Nose failure	15
7151	0	Inert	62,300			2 ea 1/2 D		
						2 ea 1/2 R	OK	16
7153	0	Inert	60,100			2 ea 1/2 D		
						2 ea 1/2 R	Nose loose but retained	16
El-2132	55	Empty	70,000			2 ea 5/8 R		
						2 ea 5/8 D		
El-2133	55	Chaff	53,700	120	112.5	2 ea 5/8 R		
						2 ea 5/8 D		
El-2134	65	Chaff	62,500	120	116	2 ea 5/8 R		
						2 ea 5/8 D		
El-2135	70	Sphere	66,300	120	120	2 ea 5/8 R		
						2 ea 5/8 D	OK	
El-2136	75	Sphere	53,800	120	120	2 ea 5/8 R		
						2 ea 5/8 D	One fin missing	18
El-2139	80	Chaff	64,500	140	?	2 ea 5/8 R		
						2 ea 5/8 D	OK	
El-2141	80	Empty	64,700			4 ea 5/8 D	Two fins missing	18
El-2154	80	Chaff	38,200	120	122	2 ea 5/8 R		
						2 ea 5/8 D	OK	
El-2155	80	Chaff	51,300	140	140	2 ea 5/8 R		
						2 ea 5/8 D	OK	
El-2156	80	Chaff	60,000	140	133	2 ea 5/8 R		
						2 ea 5/8 D	OK	
El-2159	80	Empty	52,500			4 ea 5/8 D	OK	
El-2160	75	Empty	59,500			4 ea 5/8 D	Damaged fins	
El-2161	75	TM	60,600			4 ea 5/8 D	Complete failure	
El-2162[3]	80	TM	43,800			4 ea 5/8 D	Complete failure	

TABLE II (CONTD)

METAL PARTS AND FUZING - PROTOTYPE 7-2 MODELS

Round	QE Degrees	Package	True Pressure (PSI)	Ejection Fuzing (Sec.)	Ejection Time (Sec.)	Nose Retention Pins	Condition of Model Metal Parts after Launch	Photos. Given (Fig.)
7234	0	Inert	63,000				3 Fins	19
El-2138	75	Inert	52,400				OK	19
El-2140	80	Inert	63,800				Complete failure	20
El-2157	80	Inert	63,000				Damaged fins	
El-2158	80	Inert	69,000				Fins damaged	
El-2163	80	Inert	70,000				Damaged fins	20

1 Used aluminum fin studs.

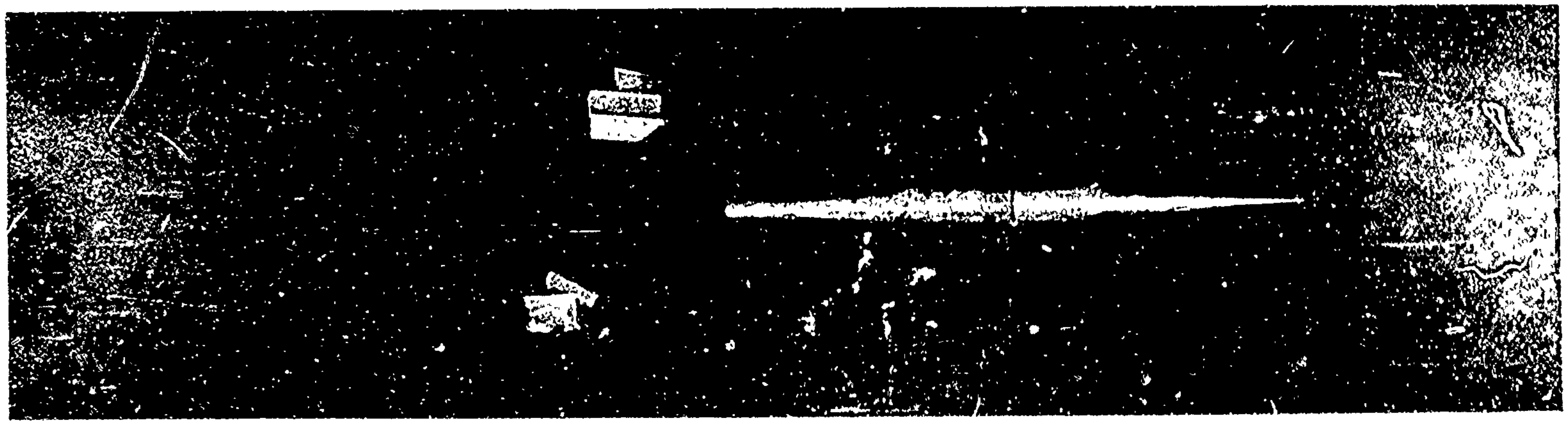
2 First two rounds use a 1/2" thick polyethylene disc, and a 1/2" thick rubber cup for obturation. All other rounds used a 2.83" thick polyethylene disc.

3 Electronics were removed before firing.

R Roll pins 15,000 pounds shear strength (5/8) each.

D Dowell pins 35,000 pounds shear strength (5/8) each.

El- Indicates rounds fired vertically at Wallops Island.



ROUND 6902

ROUND 6907

FIGURE 13. ILLUSTRATION OF PROBLEMS CAUSED BY POOR OBTURATION

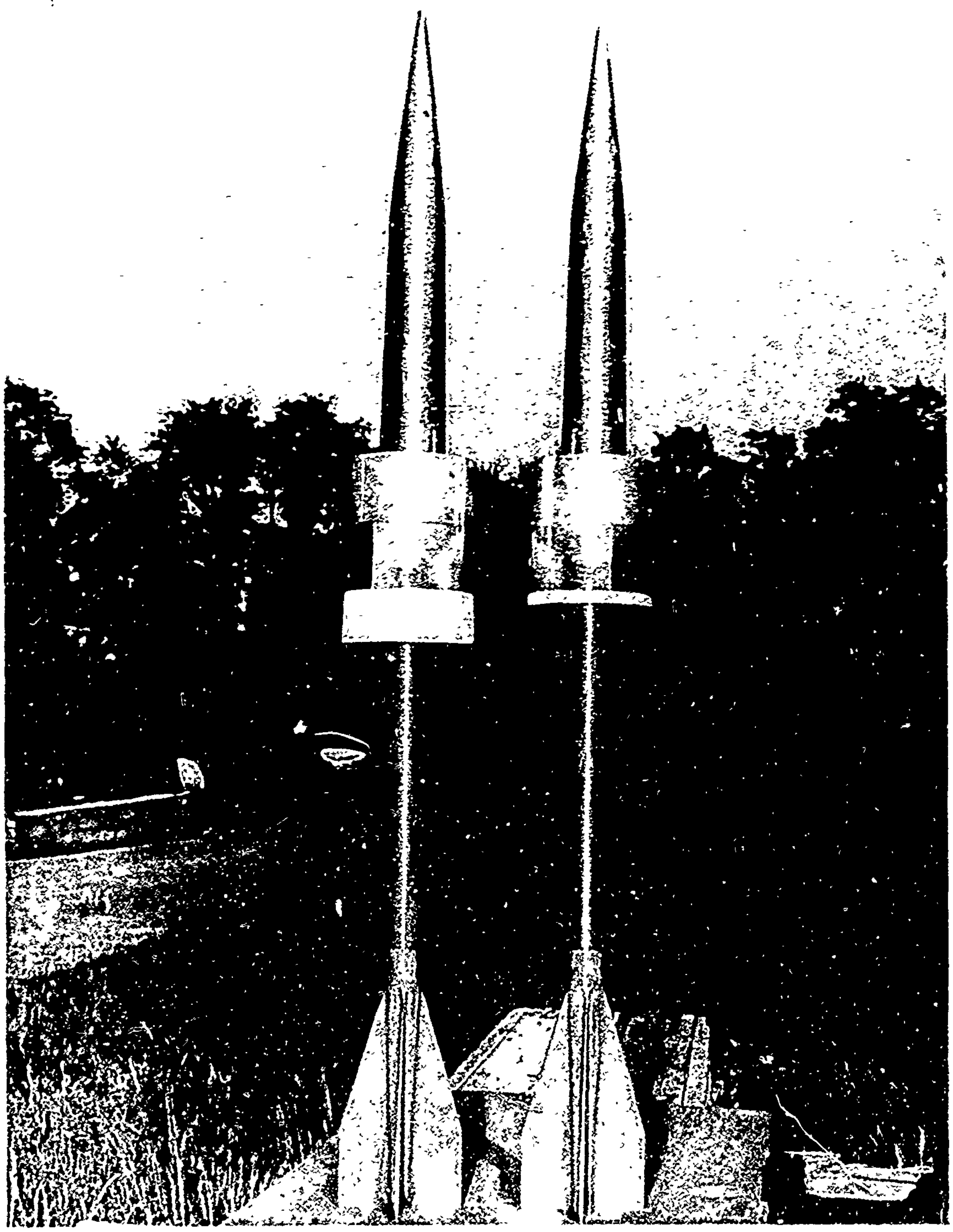
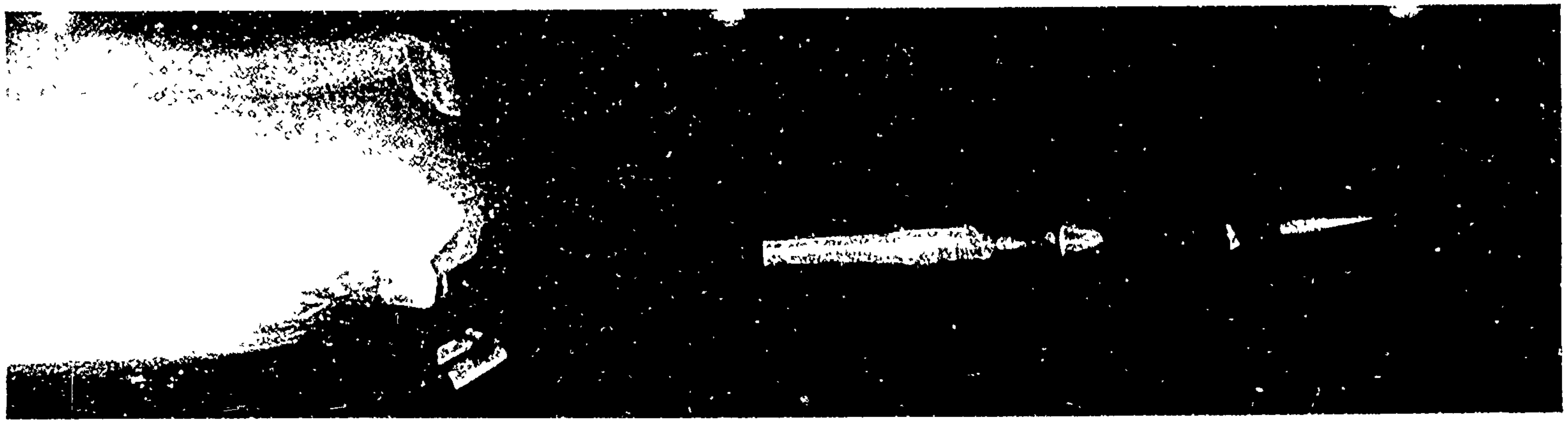
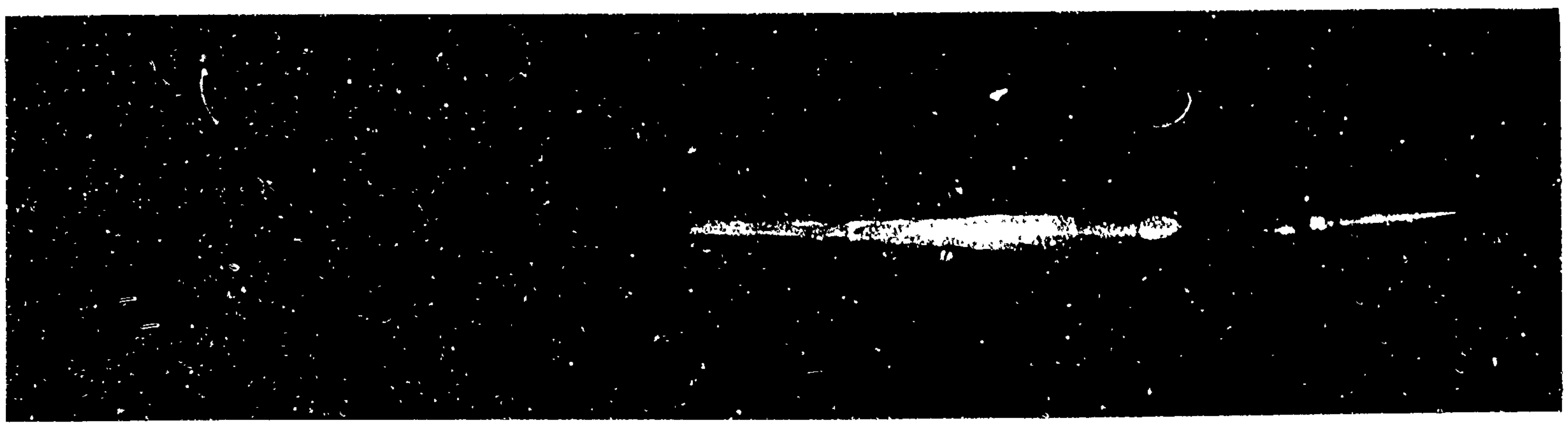


FIGURE 14. MODELS WITH POLYETHYLENE SEALS

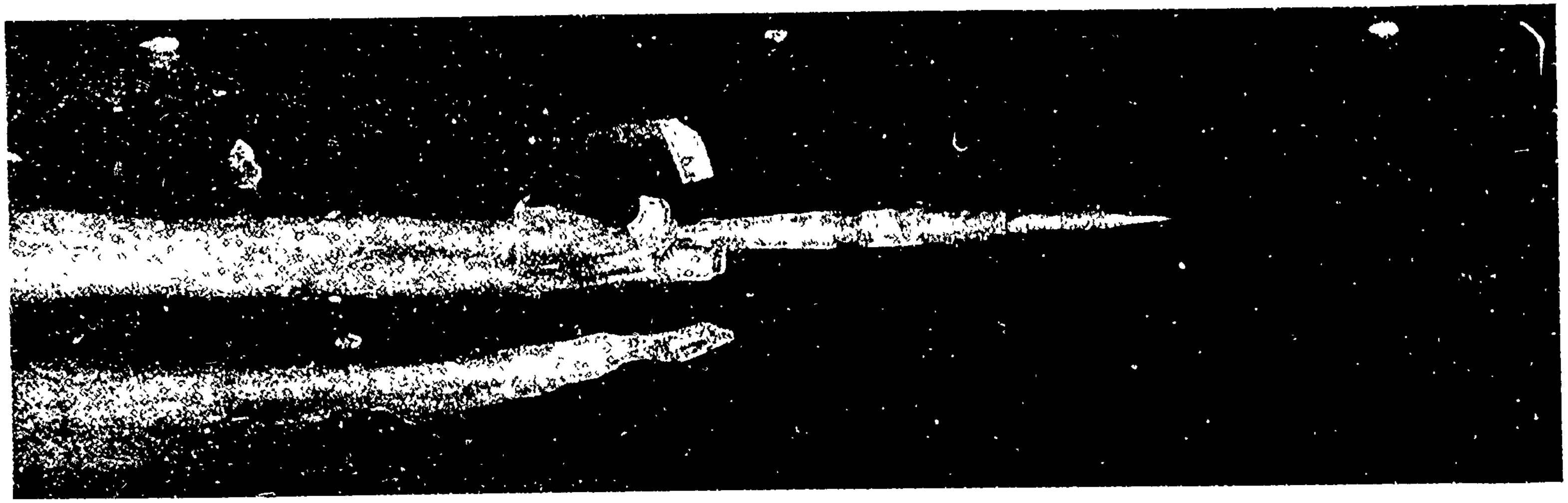


ROUND 6909

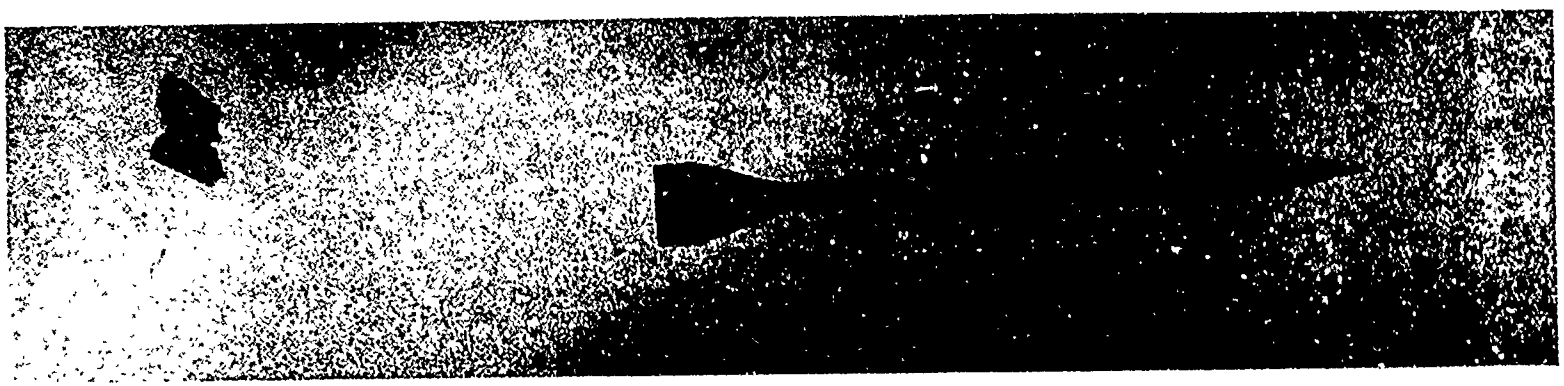


ROUND 6916

FIGURE 15. PROJECTILE NOSE RETENTION PROBLEMS



ROUND 7151



ROUND 7153

FIGURE 16. LOOSENED NOSES

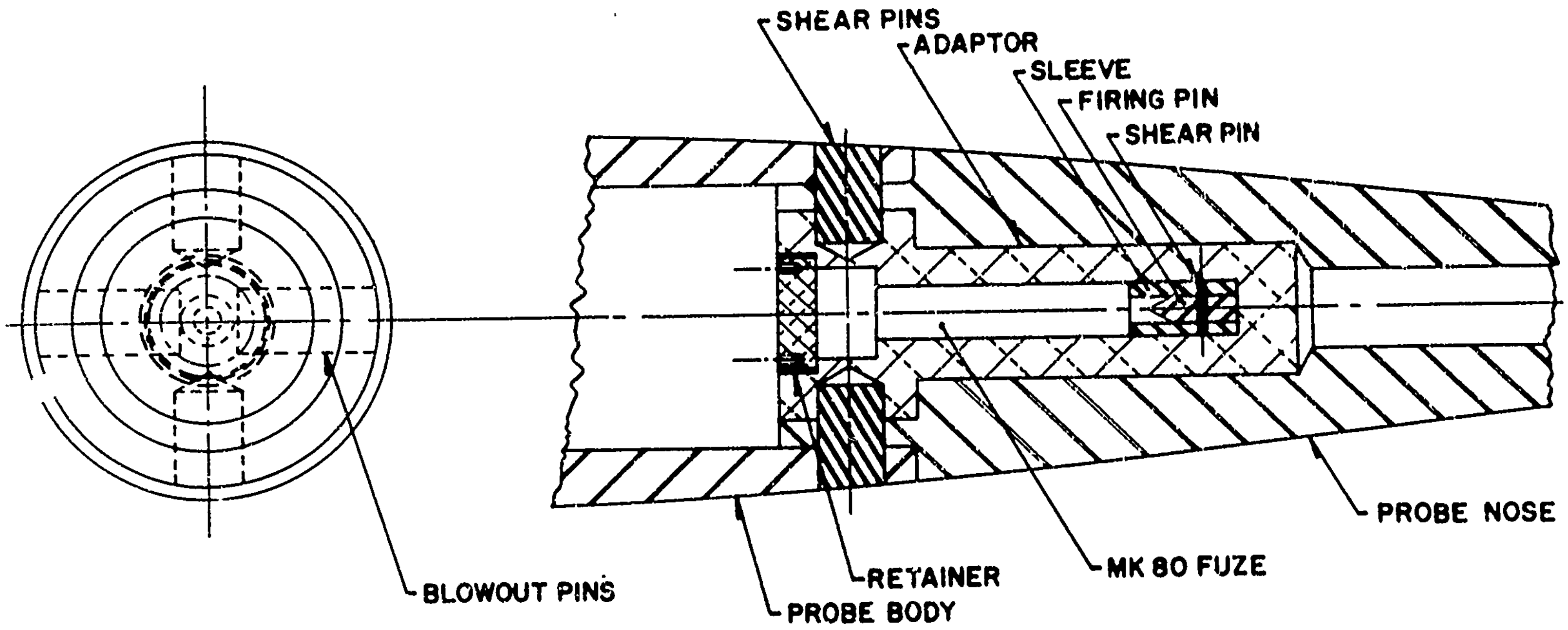
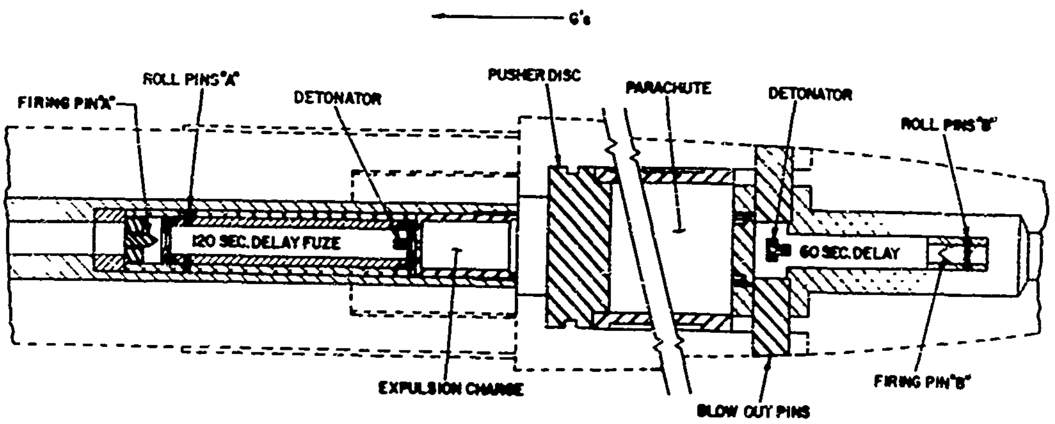


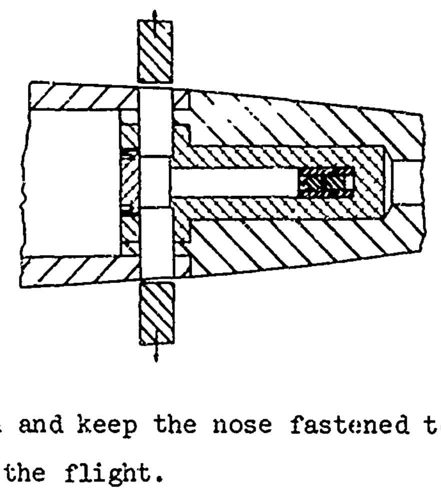
FIGURE 17. 7-INCH PROBE PROJECTILE - NOSE EJECTION SYSTEM

roll pins (26,000 pounds shear strength) and two 3/8-inch steel dowel pins (65,000 pounds shear strength). This type of projectile system was designed to accommodate an ejection type payload.

The payload (parachute) ejection system is shown in Figures 5 and 17 and described in the following sections; refer also to the un-numbered figures following.

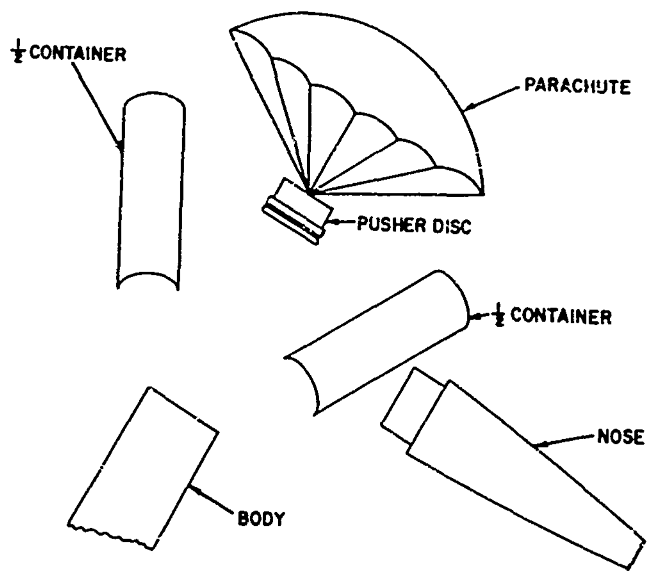


As the projectile is launched the roll pins (A and B) are sheared. The 120 second delay fuze moves back to the firing pin A, and pin B moves back to the 60 second delay fuze. This action initiates the delay fuzes. At 60 seconds the first detonator is initiated, ejecting the blow out pins perpendicular to the missile's axis.



The shear pins remain and keep the nose fastened to the projectile throughout the remainder of the flight.

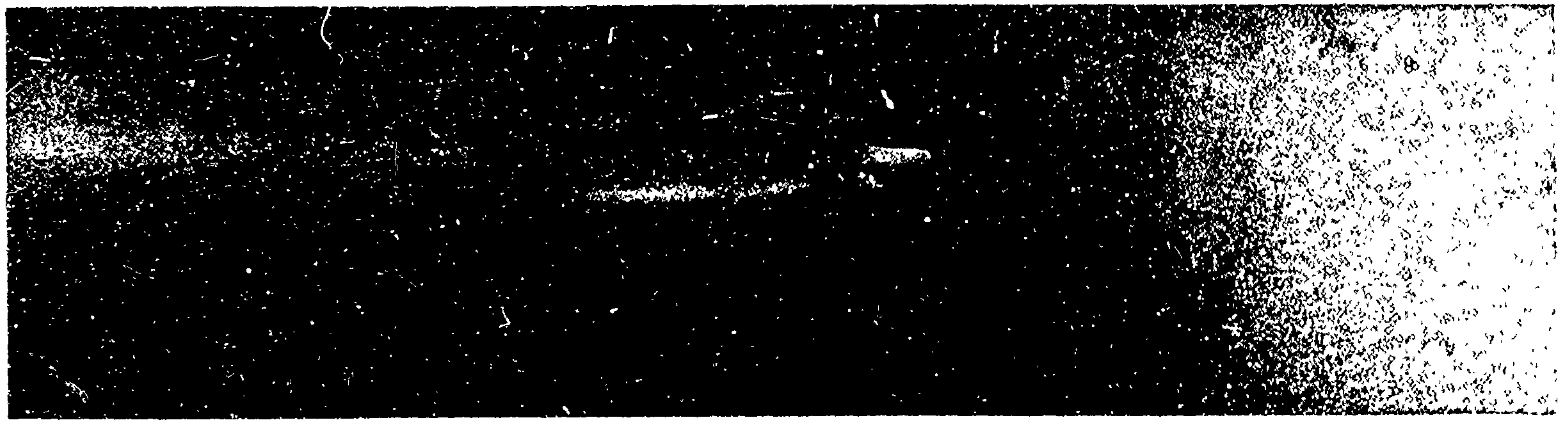
At 120 seconds the second detonator is initiated. This detonator ignites the expulsion charge. The vehicle now acts as a small gun. Pressure is transferred through the pusher disc and parachute container to the base of the nose. The shear pins are now sheared and the payload is ejected at a velocity of 300 fps. The container, being split before assembly, is free to fall away from the parachute.



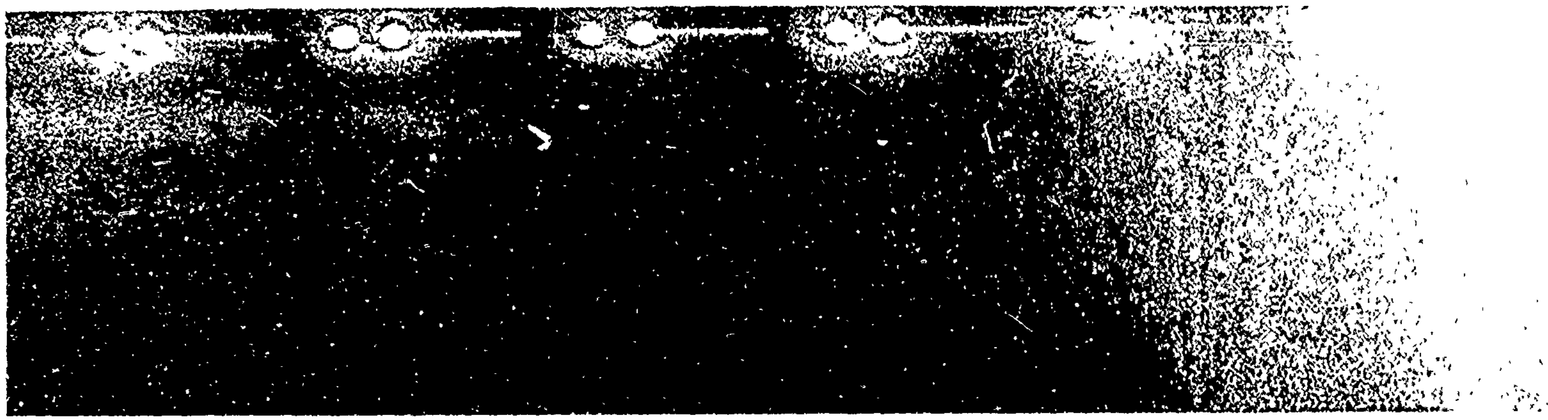
The fin damage incurred by the 7-0 models was not considered excessive during these early stages of development. Of the 18 models fired (fins riding bore of tube) one lost all fin blades, one lost two fins, and one lost one fin, Figure 18. The three finned vehicle attained essentially the planned apogee.*

Two of the 7-0 projectiles carried 1750 Mc/s telemetry systems; both of these projectiles broke-up completely in the gun, the second at a chamber pressure of only 40,000 psi. The basic telemetry package had been flown from the 5-inch HARP gun probe system several times at much higher load levels with no failures. The models for the 7-inch gun did,

During the preparation of this report 19 models were fired (with a quarter inch bore clearance) and no fin damage was observed.



ROUND EI-2136



ROUND EI-2141

FIGURE 18. FIN PROBLEMS

however, employ a new antenna; this was on the tail and wiring was led out to it from inside the vehicle. This could have permitted the gun gases to get inside the projectile and lead to failure.

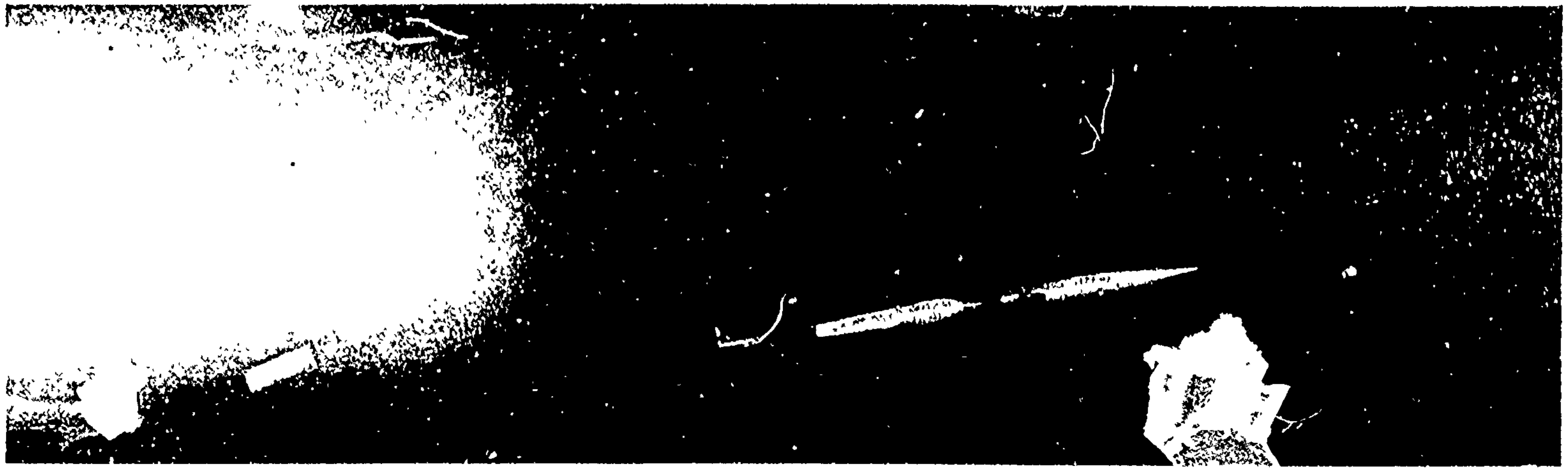
The metal parts behavior of the 7-2 models (3-inch prototype) was somewhat discouraging; of 6 rounds fired, only 1 was launched entirely successfully. The other rounds all experienced severe fin damage; 1 round failed completely, Figures 19 and 20. This fin damage is either caused by the hot environment of the powder gases, or the discarding of the sabot. Investigation of the cause of this fin damage will be the subject of future tests. A cut away view of the model in the sabot is given in Figure 21.

3.2 Tube Structural Performance

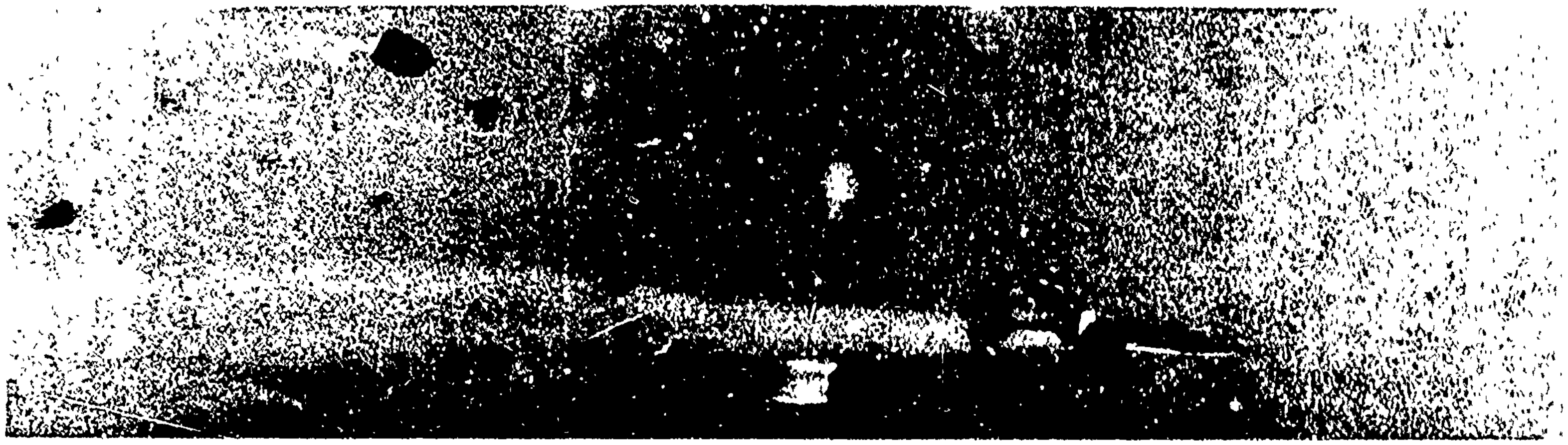
The results of the tube tests to date are fairly simply stated. The Serial No. 1 tube "O"-ring joint seal failed after the fifth shot at an estimated local pressure of 20,000 psi. The seal was replaced and further tests of the Serial No. 1 and No. 2 tubes were conducted with modified charge compositions in order to prevent pressures of this magnitude from occurring at the juncture. A total of 29 more shots were fired, 11 with breech pressures exceeding 60,000 psi. One more shot was fired with an experimental charge that gave an unexpectedly high pressure, estimated at 90,000 psi; although the breech plug failed, the tube survived. It was concluded that the first two tubes were adequate, within the known limitations of the joint position and design. Design pressure-travel curves for the tubes are given in Figure 22.

The newer joint design, represented by Serial No. 3 tube, was tested in 16 firings; breech pressures exceeded 60,000 psi 8 times, with 2 shots at about 70,000 psi. In these high pressure cases it is estimated that the pressure at the joint exceeded 25,000 psi. No adverse effects were noted, and it was concluded that the revised design was adequate.

In vertical fire, the modified T76 mount performed satisfactorily at all test conditions. In general, horizontal tests should not be conducted at breech pressures exceeding 50,000 psi because of excessive recoil.

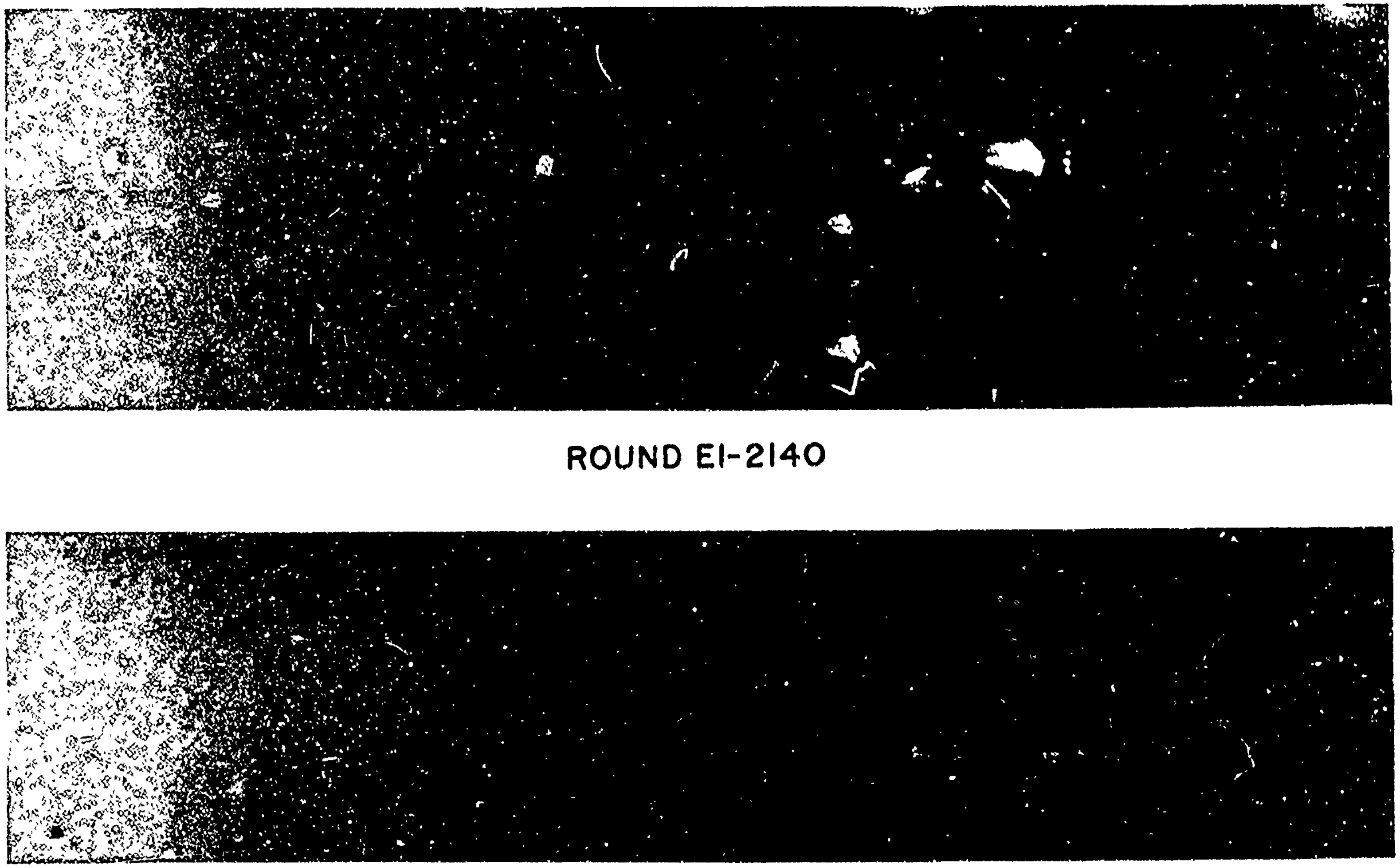


ROUND 7234



ROUND EI-2138

FIGURE 19. 7-2 MODEL PROJECTILES



ROUND EI-2140

ROUND EI-2162

FIGURE 20. FAILURES OF 7-2 MODEL PROJECTILES

FIGURE 21. 7-2 MODEL IN SABOT

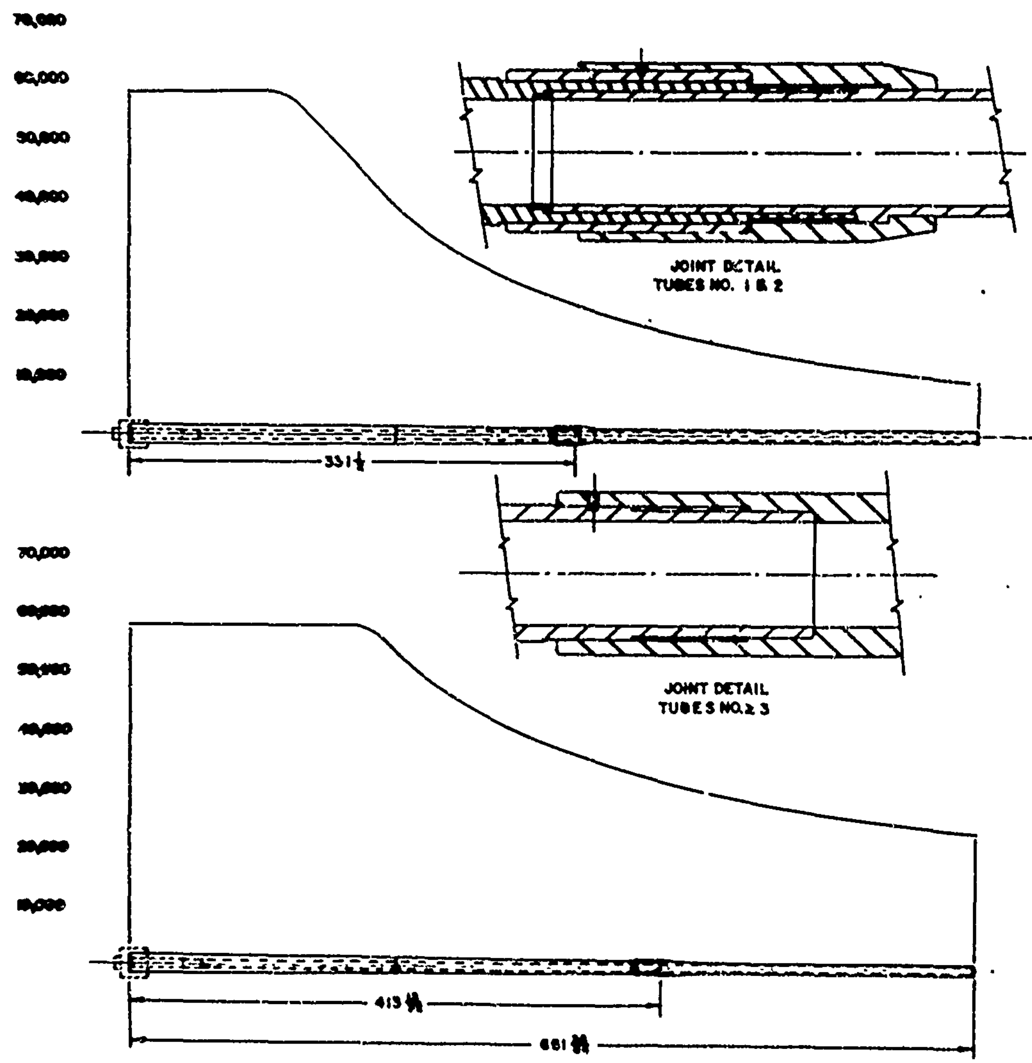


FIGURE 22. DESIGN PRESSURE CURVES 7-INCH PROBE TUBES

3.3 Charge Development

The charge development tests were all of an interim nature. The first attempts were to develop a charge from existing M17 propellant that would yield a reasonable performance from the first two gun tubes. It was not, however, expected that the currently available M17 propellant would yield an optimum charge, even for the higher performance tubes.

The tests can be catagorized in three series:

a. A series to obtain an interim charge for the Serial No. 1 and No. 2 tubes.
b. A series to change the mixture to better utilize the strength of the No. 3 tubes and to launch two different projectile weights.
c. A very short series to try to improve on the erratic high-pressure performance of Series b.

The data are presented in Table III and Figures 23 and 24. Figure 10 shows the basic construction of the charges. The first series started out with M17 composition, 0.079-inch web MP, and evolved into a bi-grain mixture using 0.079 and 0.052-inch web. This propellant mixture came about because of the necessity to restrict the pressure at the tube joint. Chamber pressure data provided by the strain gages were used to construct graphs of pressure versus time. The pressure-time traces were relatively smooth with some indications of changes in the burning rate (Figure 25 shows a series of pressure-time curves for various charge weights). These charges produced considerable variation in pressure and velocity. They were adequate for their limited purpose, however.

The horizontal phase of Series b was very short due to the horizontal recoil limitations. The theoretical prediction that 0.114-inch web was most practical for the 80 pound shot weight, and that a mixture of 0.079 and 0.114-inch web was near optimum for the 50 pound shot weight seemed to be borne out. The horizontal tests used only the 0.114-inch

TABLE III

INTERIOR BALLISTICS FOR TUBES NO.1 AND NO. 2

Round	In-Gun Wt. (Lbs.)	Total Charge (Lbs.)	True Pressure (PSI)	Velocity (Ft./Sec.)	Propellant Charge* % (By Wt.)	Web (Size)	% (By Wt.)	Web (Size)	Model Loading Distance (Inches from Breech)
6864 [1]	71.5	20	6,000	1720	100	.079			90.4
6865 [1]	71.5	36	8,000	2700	100	.079			90.5
6866 [1]	71.5	50	16,000	3520	100	.079			90.5
6867 [1]	71.5	65	32,000	4380	100	.079			90.5
6868 [1,2]	71.5	65	32,800	4390	100	.079			90.5
6896 [1]	71.5	65	39,200	4500	80	.079	20	.052	90.5
6897 [1]	71.5	70	44,800	4690	80	.079	20	.052	90.5
6898 [1]	71.5	73	51,900	4780	80	.079	20	.052	90.5
6899 [1]	71.5	75	50,800	4780	80	.079	20	.052	90.5
6900 [1]	71.5	78	60,000	5100	80	.079	20	.052	90.5
6902	79.2	56	31,000	4010	80	.079	20	.052	93.1
6906 [1]	78.8	75	52,800	4770	85	.079	15	.052	90.5
6907	79.2	75	59,200		85	.079	15	.052	93.1
6909	81.8	73	52,600		85	.079	15	.052	93.1
6916	82.6	73	51,700	4740	85	.079	15	.052	93.1
7148 [1,3]	79.0	60	30,000	4180	80	.079	20	.052	90.5
7149 [1,3]	78.8	65	37,000	4480	80	.079	20	.052	90.5
7150 [1,3]	78.8	70	47,000	4700	80	.079	20	.052	90.5
7151 [3]	81.5	75	62,300	5050	80	.079	20	.052	93.0
7153 [3]	81.2	78	60,100		80	.079	20	.052	93.0
E1-2132 [3]	74.5	78	70,000	5000	80	.079	20	.052	93.0
E1-2133 [3]	81.0	75	53,700	4670	80	.079	20	.052	93.0
E1-2134 [3]	78.0	78	62,500	4890	80	.079	20	.052	93.0
E1-2135 [3]	80.3	78	66,300	4840	80	.079	20	.052	93.0
E1-2136 [3]	80.0	78	60,000	4850	80	.079	20	.052	93.0
E1-2139 [3]	77.5	80	64,500	4940	80	.079	20	.052	93.0
E1-2141 [3]	75.0	80	64,700	5020	80	.079	20	.052	93.0
7152 [1,3]	51.1	65	30,000	4800	80	.079	20	.052	90.5
E1-2131 [1,3]	51.5	75	42,000		80	.079	20	.052	90.5
E1-2137 [1,3]	51.5	82	53,800		80	.079	20	.052	90.5
E1-2138 [3]	47.0	84	52,400	5820	80	.079	20	.052	93.0
E1-2140 [3]	47.0	89	63,800		80	.079	20	.052	93.0

* See Figure 10 for construction

1 Proof slugs

2 Tube lost seal at joint

3 Tube Serial No. 2

TABLE III (CONTD)

INTERIOR BALLISTICS FOR TUBE NO. 3

Round	In-Gun Wt. (Lbs.)	Total Charge (Lbs.)	True Pressure (PSI)	Velocity (Ft./Sec.)	Propellant Charge* % (By Wt.)	Web (Size)	% (By Wt.)	Web (Size)	Model Loading Distance (Inches from Breech)
7230 [1]	78.8	80	22,800	3900	100	.114			115.0
7233 [1]	78.8	95	34,900	4600	100	.114			115.0
E1-2154	81.0	100	38,200	4500	100	.114			116.0
E1-2155	80.9	110	51,300	5010	100	.114			116.0
E1-2156	80.7	116	60,000	5220	100	.114			116.0
E1-2159	72.0	116	52,500	5220	100	.114			119.0
E1-2160	72.1	90	59,500		80	.078	20	.114	119.0
E1-2161	69.1	94	60,600		75	.078	25	.114	119.0
E1-2162	65.5	76	43,800		80	.079	20	.052	119.0
7231 [1]	47.2	80	34,600	4800	80	.079	20	.114	114.7
7232 [1]	47.2	95	53,200	5600	80	.079	20	.114	115.0
7234	50.1	100	63,000	6000	80	.079	20	.114	117.0
E1-2142 [1]	51.4	100	63,800	5780	75	.078	25	.114	115.0
E1-2157	49.3	102	63,000	5850	80	.078	20	.114	116.4
E1-2158	45.3	104	69,000	6080	80	.078	20	.114	117.0
E1-2163 [4]	46.3	103	70,000		80	.078	20	.114	119.0

* See Figure 10 for construction

1 Proof slugs

4 First four increments used 80% .078 and 20% .114 web. Increment 5 (19 lbs.) used 80% .078 and 20% .052 web.

TABLE III (CONTD)

INTERIOR BALLISTICS FOR STACKED POWER, TUBE NO. 1

Round	In-Gun Wt. (Lbs.)	Total Charge (Lbs.)	True Pressure (PSI)	Velocity (Ft./Sec.)	Propellant Charge* % (By Wt.)	Web (Size)	% (By Wt.)	Web (Size)	Model Loading Distance (Inches from Breech)
7328 [1]	79.0	74	40,200	4400	73	.114	27	.079	90.5
7329 [1]	79.0	86			77	.114	23	.079	90.5

Powder stacked by the Naval Propellant Plant.
All .079 web powder stacked in last increment.

1 Proof of slugs

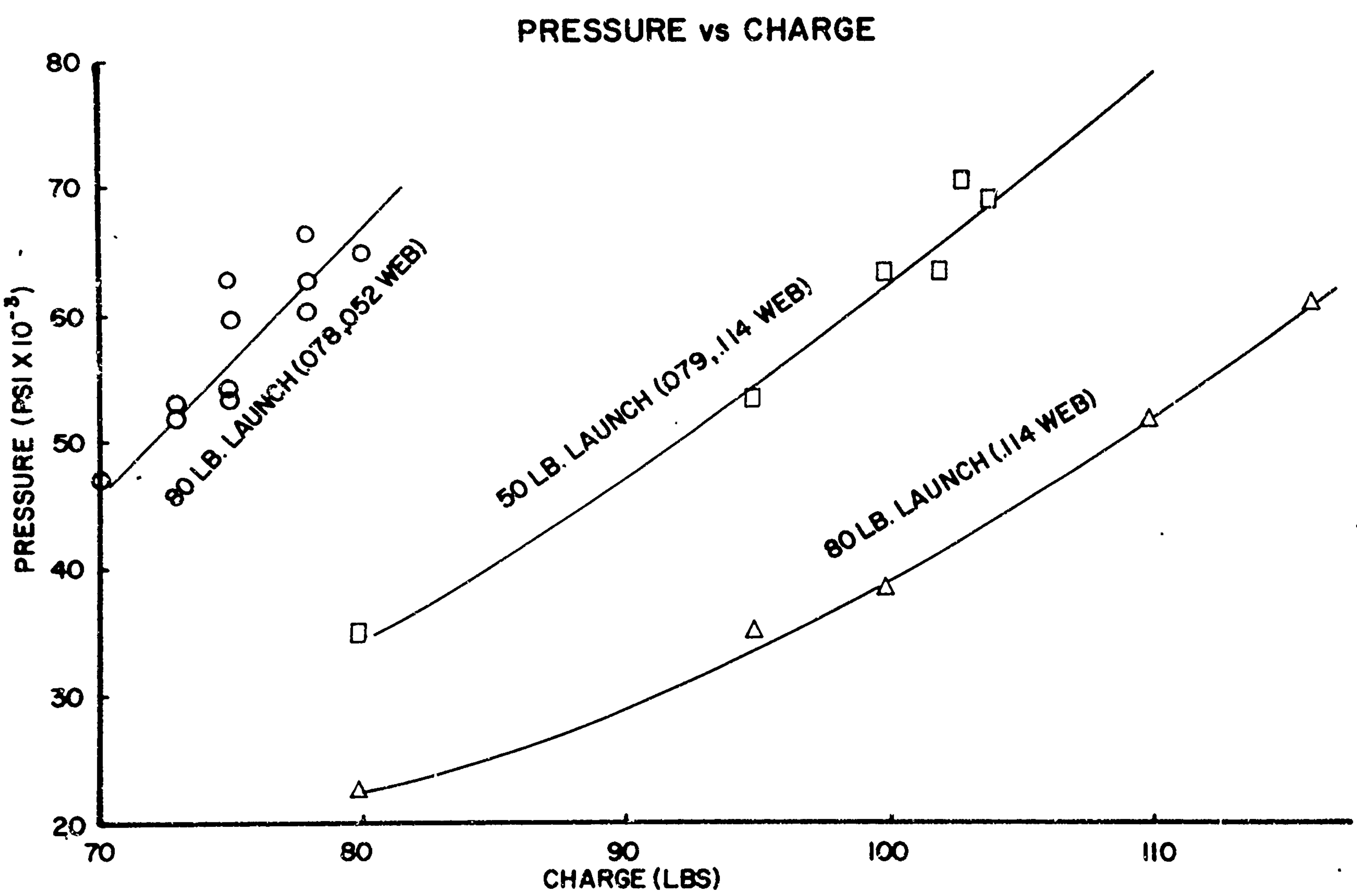


FIGURE 23. PRESSURE AS A FUNCTION OF CHARGE WEIGHT

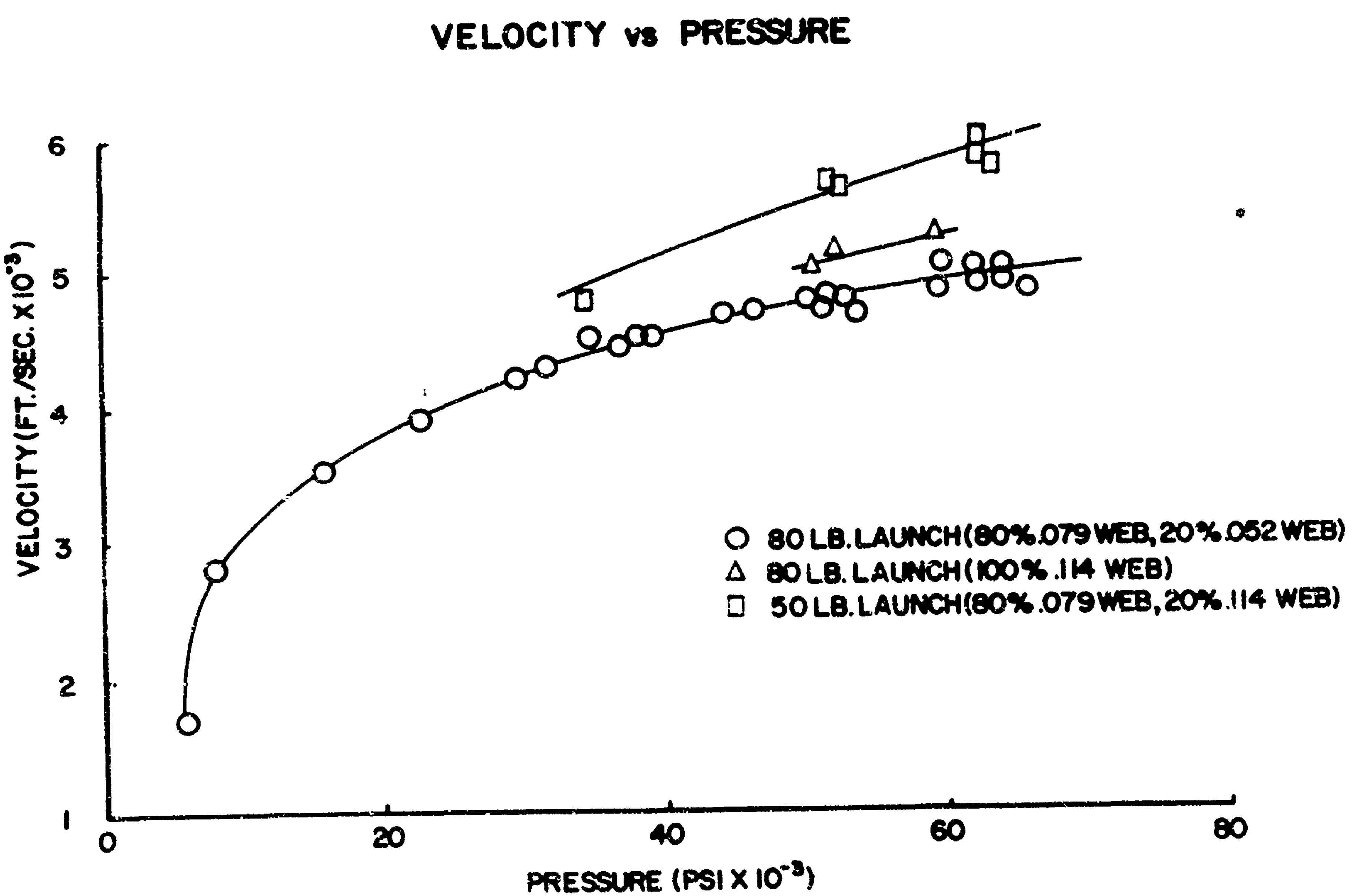


FIGURE 24. PROJECTILE VELOCITY AS A FUNCTION OF PRESSURE

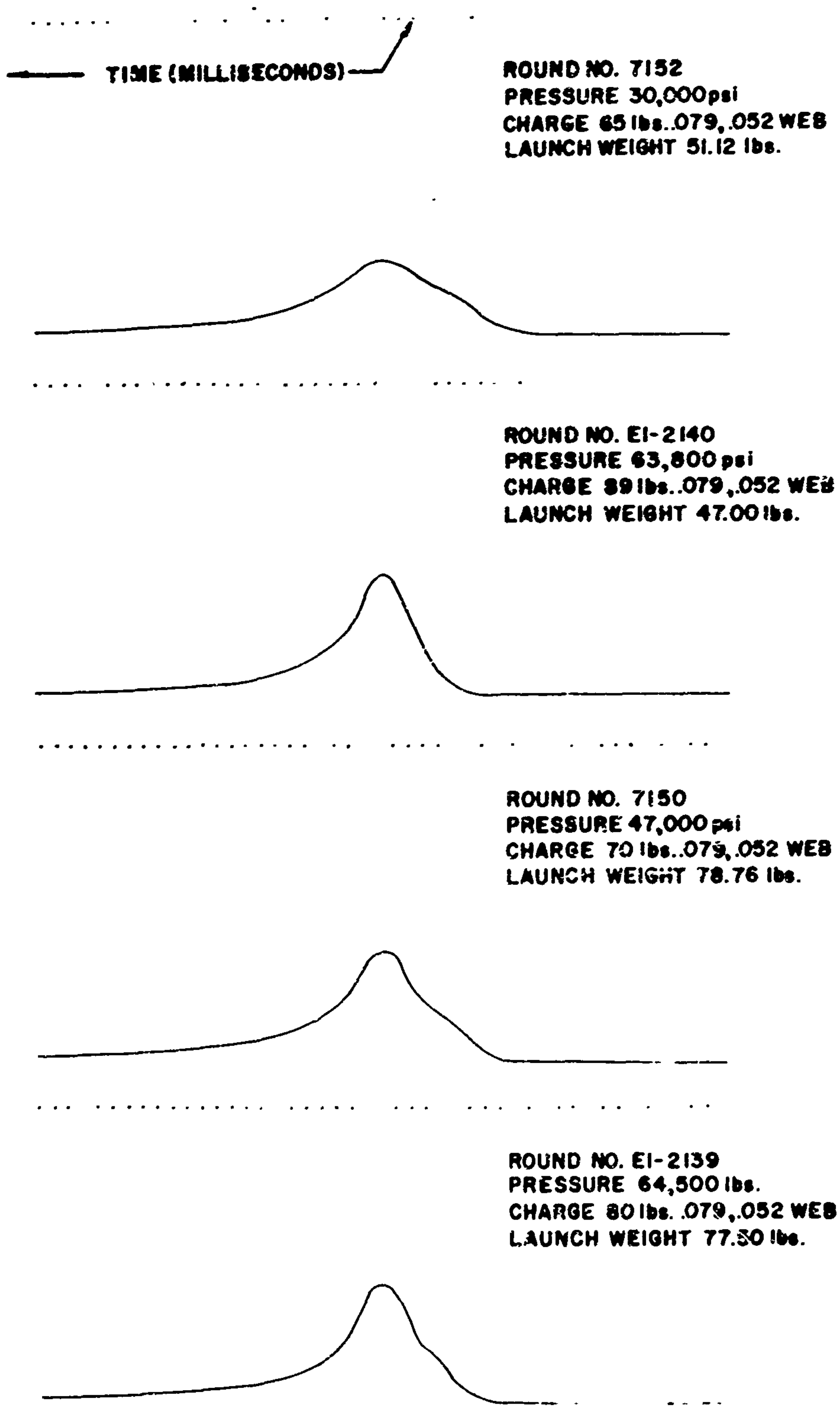


FIGURE 25. BREECH PRESSURE VERSUS TIME - VARIATION IN LAUNCH WEIGHT

web propellant. Tests of the 0.079 and 0.114-inch web mixture for the lighter shot weight produced fairly smooth pressure-time curves and lower pressure versus charge slope ratio than the "a" series. The vertical-fire portion of the series yielded pressures higher than expected. High oscillations in the pressure-time trace were observed in the case of the 0.114-inch web, Figure 26; and sharp changes in pressure-time slope in the case of the bi-grain mix were observed, Figure 27. Either type of behavior is highly objectionable.

In general, the pressure-time curves were smoothly varying only up to breech pressures of about 45,000 psi; at high pressures they were not. Actual pressure spikes up to 30 percent above computed pressures occurred.

The third test series was an attempt to use the Navy-style stacked charge* with a large ignition pad weight to charge weight ratio. The pressure-time trace for the first shot looked adequately smooth, but the second shot blew-out the breech plug.

The propellant-ignition system provided satisfactory performance, but further work is required to develop the optimum charge. Additional work with the assistance of the Interior Ballistics Laboratory and Picatinny Arsenal appears to have yielded a usable, but still not optimum, 0.114-inch web charge for the 80 pound shot weight. The use of lighter shot weights with this web charge has not been adequately explored.

3.4 Flight Performance and Event Packages

Based upon measured velocities, undamaged projectiles nearly always attained the maximum altitudes predicted. The maximum altitude reached by the 7-0 projectile was 260,000 feet, and for the prototype of the 7-2, 330,000 feet. Predicted trajectories for the 7-0 projectile are shown in Figures 28 through 31. The major problem experienced during the initial tests was the variation in velocity; this variation is caused by

The powder grains were oriented and stacked one on top of the other in the bagged charge rather than being bagged loosely in random orientations. The latter condition is the usual case for Army bagged charges.

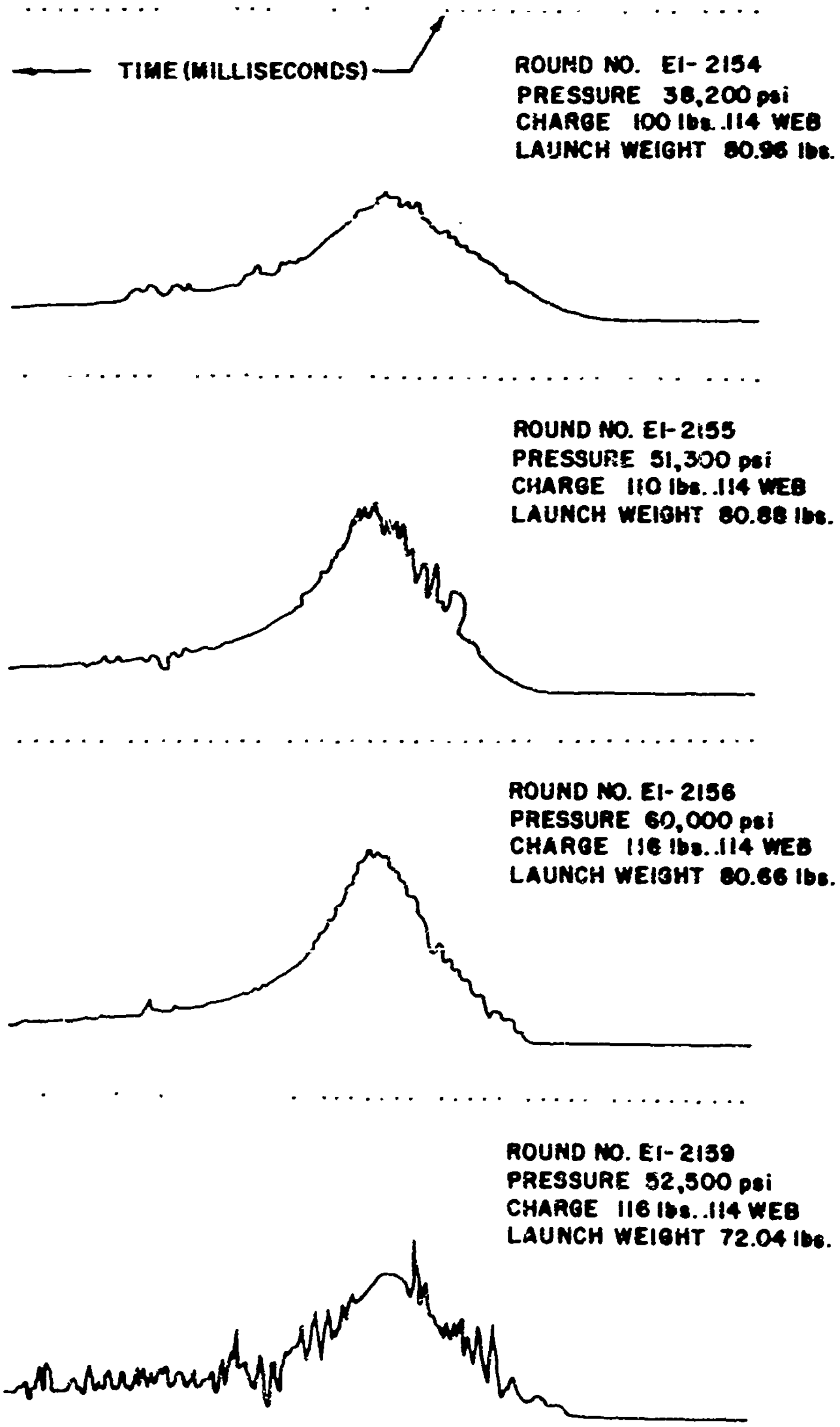


FIGURE 26. BREECH PRESSURE VERSUS TIME - OSCILLATIONS, .114 WEB PROPELLANT

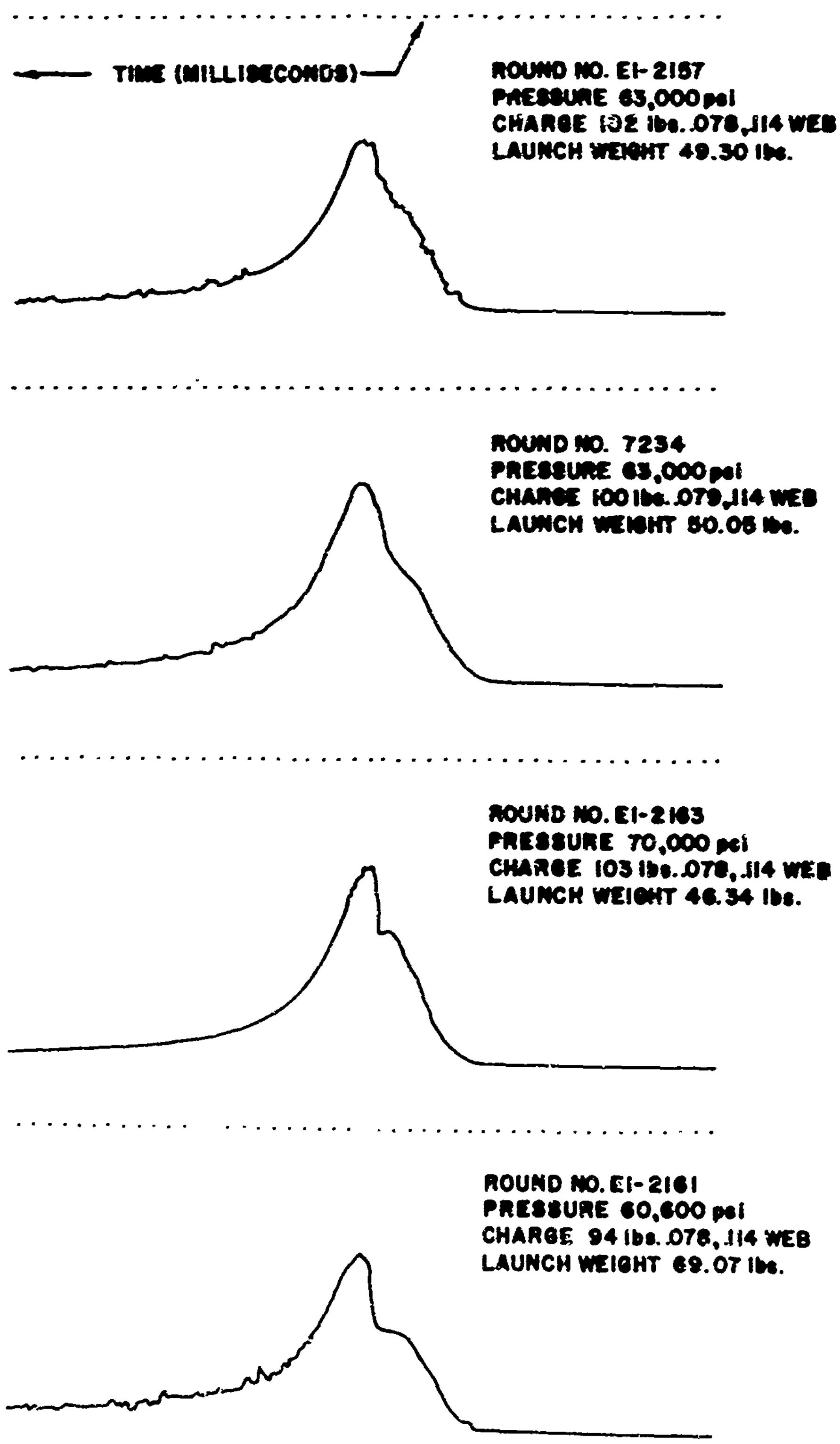


FIGURE 27. BREECH PRESSURE VERSUS TIME - VARIATIONS IN BURNING RATE

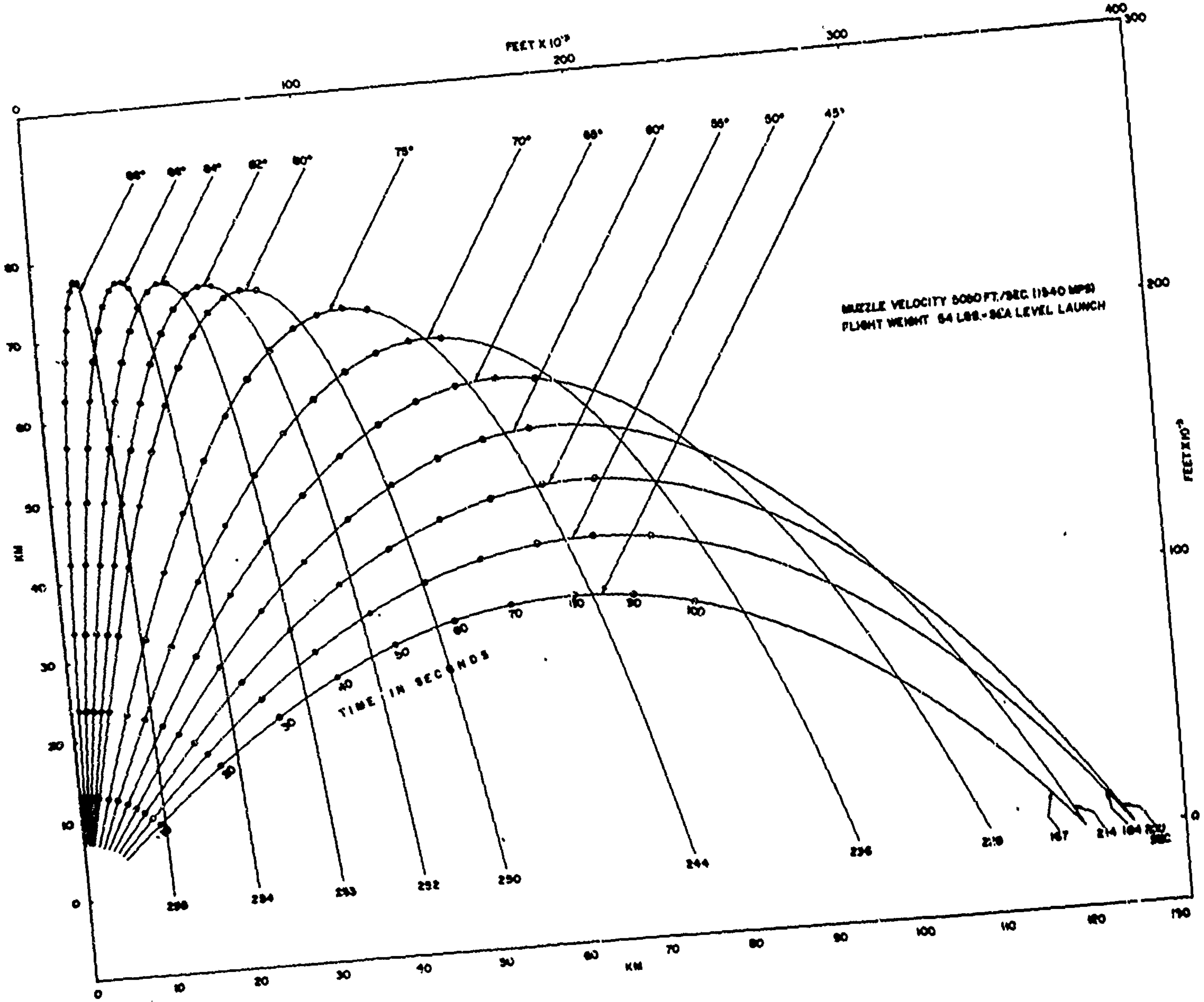


FIGURE 28. HARP 7-0 PROBE TRAJECTORIES

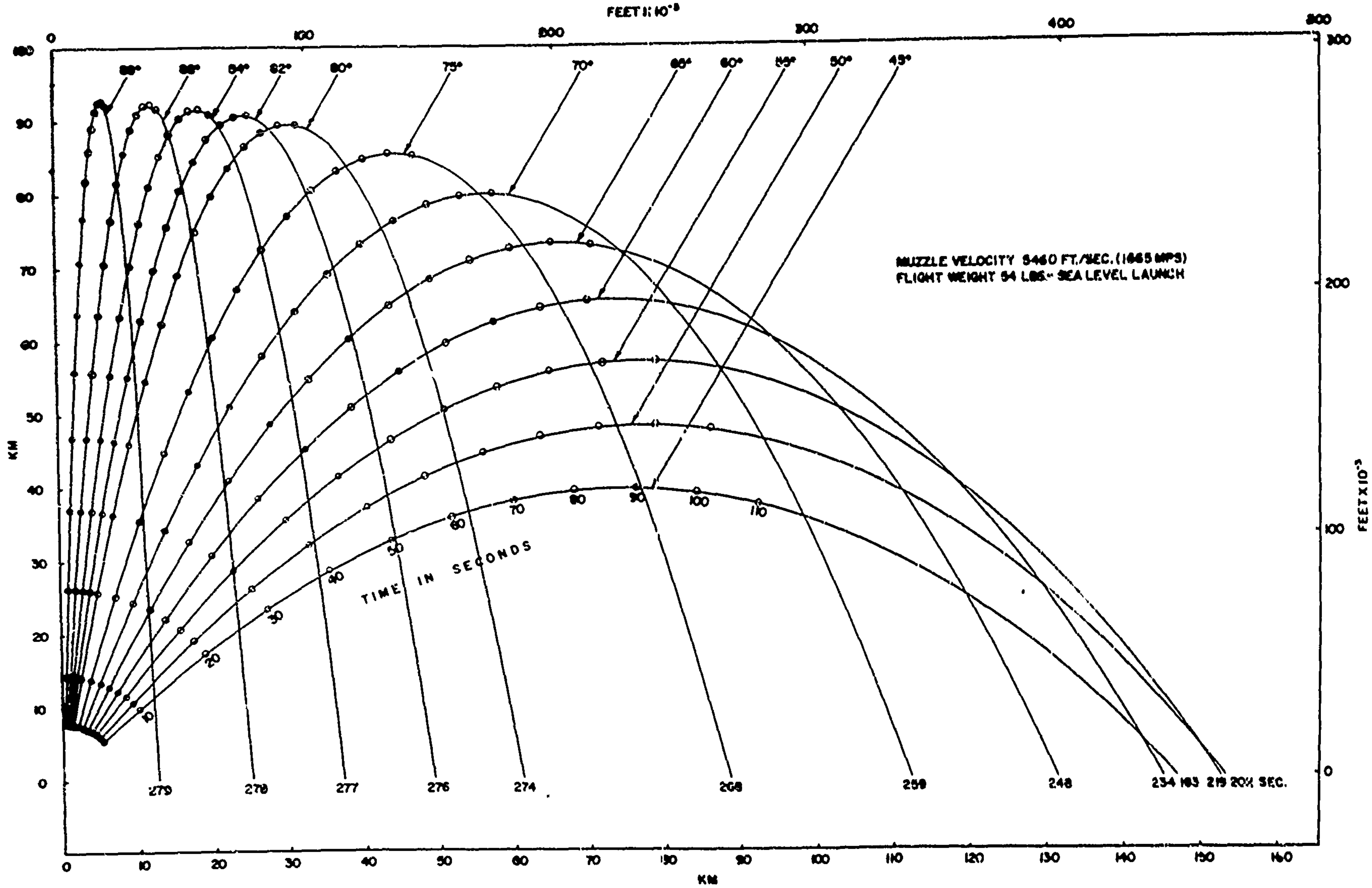


FIGURE 29. HARP 7-0 PROBE TRAJECTORIES

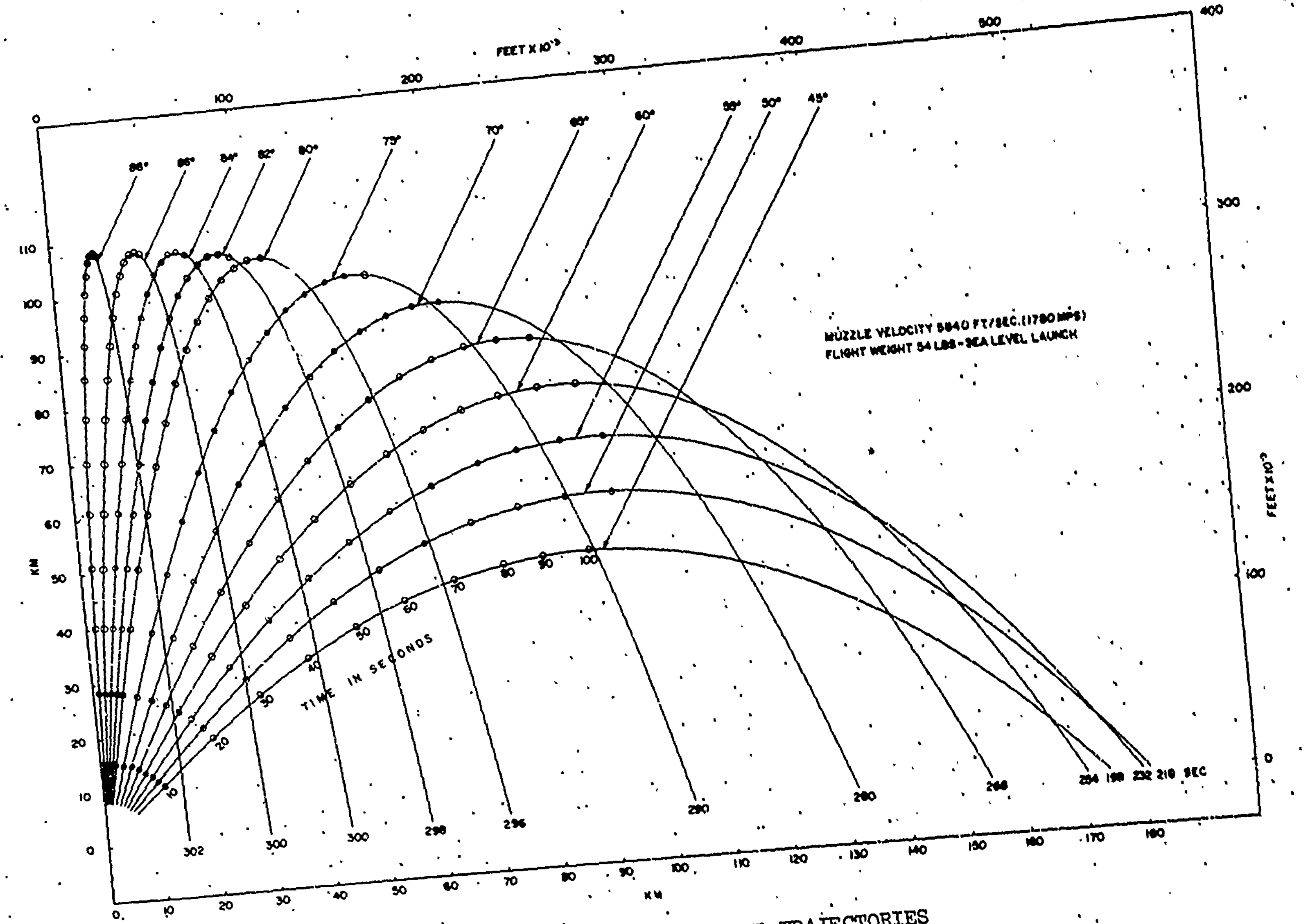


FIGURE 30: HARP 7-0 PROBE TRAJECTORIES

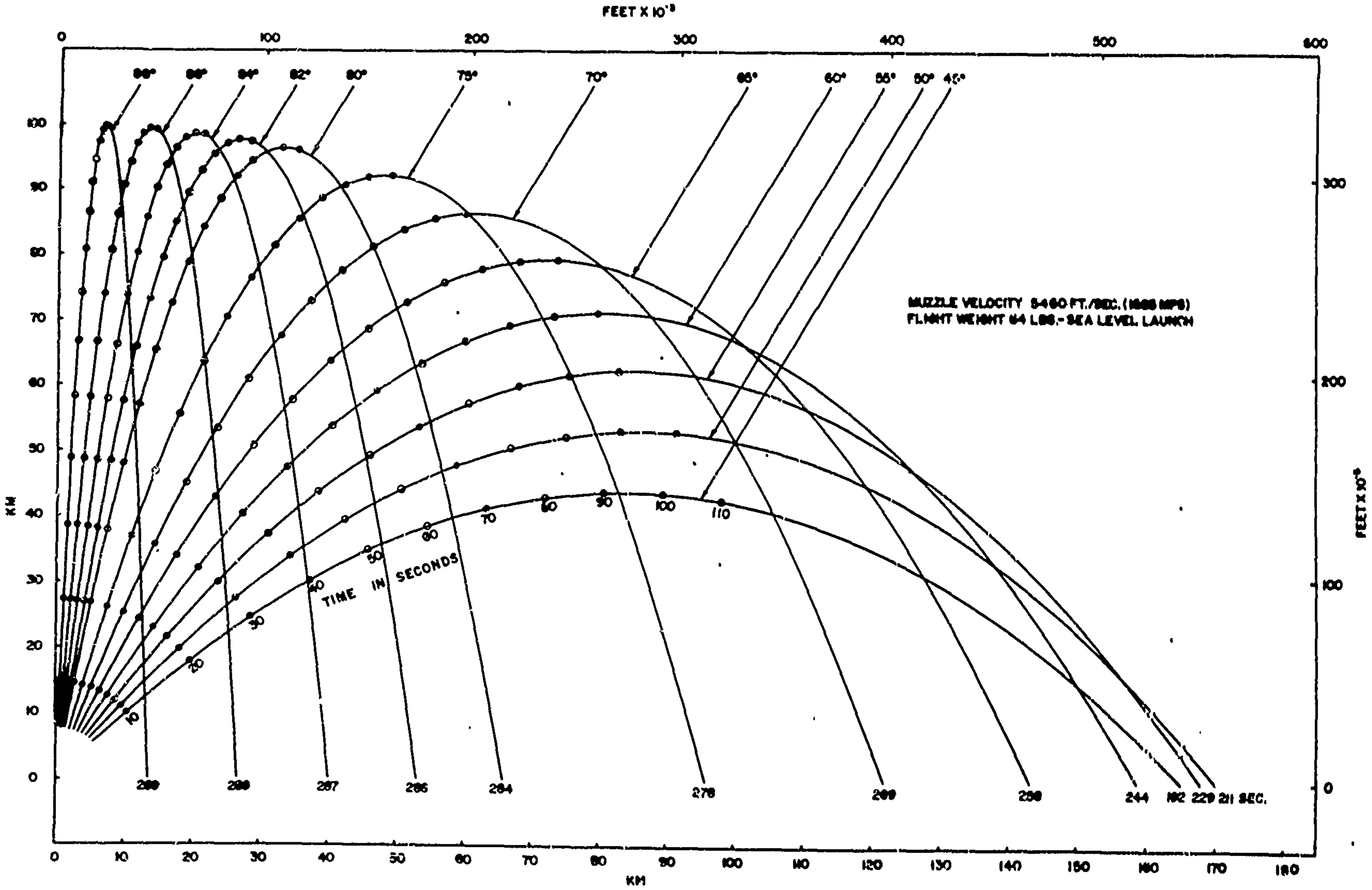


FIGURE 31. HARP 7-0 PROBE TRAJECTORIES

the erratic high pressures involved with the use of large charges. The data and comments on each round are given in Table IV. A review of the data from the thirteen 4.0-inch diameter rounds shows satisfactory flights for ten rounds. Of the unsatisfactory flights, one projectile lost two fins; one had all fins damaged; a third projectile; with no apparent damage visible in the launch films, had poor performance. This last projectile is the only vehicle with no obvious explanation for its poor performance.

The flight performance of the prototype 7-2 vehicle was as predicted for intact projectiles; but serious fin damage was the rule. Part of the fin problem was attributable to the early development state of the vehicle and part to the erratic pressures which resulted in loads above the design limits.

Event packages with the exception of the TM units, were carried primarily to test the dual fuzing system. Four types of packages were carried:

a. A chaff package of X-band chaff, scaled up from a successful 5-inch unit. This type of chaff had been ejected from the 5-inch system projectile and tracked on many occasions.
b. A 16-inch diameter corner-reflector sphere package. This was a new package and was not flown successfully in two tries from the 5-inch system.
c. An experimental, tungsten, dipole, S and C-band, rope chaff package.
d. An experimental 1750 megacycle telemetering package. A similar unit had two successful flights from the 5-inch system.

In general, the dual fuzing system functioned satisfactorily in all cases except one. The X-band chaff proved to be acceptable with this system. The corner-reflector spheres and rope chaff were ejected, but

TABLE IV

VERTICAL FLIGHT PERFORMANCE - 7-0 PROJECTILE

Round	Payload	Flight Wt. Lbs.	QE Degrees	Maximum Alt. Ft.	Performance Comments
E1-2131	Slug	51.5	55		Radar did not acquire.
E1-2132	Empty	57.9	55		Radar did not acquire.
E1-2133	Chaff	64.2	55	137,900	Good.
E1-2134	Chaff	61.4	65	203,000	Good.
E1-2135	Sphere	63.1	70	215,700	Altitude good, payload did not function.
E1-2136	Sphere	62.5	75	222,600	Altitude good, payload did not function.
E1-2137	Slug	51.5	75	8,400	Good.
E1-2139	Chaff	61.0	80	253,300	Altitude good, no ejection.
E1-2141	Empty	58.2	80	130,500	Altitude short, lost two fins.
E1-2142	Slug	51.4	80	8,500	Good.
E1-2154	Rope Chaff	64.3	80	207,700	Altitude good, payload did not function.
E1-2155	Rope Chaff	64.2	80	259,900	Altitude good, payload did not function.
E1-2156	Rope Chaff	64.0	80	94,600	Poor altitude
E1-2159	Empty	55.4	80	239,000	Good.
E1-2160	Empty	55.5	75		Damaged fins.
E1-2161	TM	52.5	75		Model failure.
E1-2162 *	TM	48.9	80		Model failure.
			Prototype 7-2 Projectile		
E1-2138	Inert	28.8	75	328,600	Good.
E1-2140	Inert	27.6	80		Model failed.
E1-2157	Inert	29.2	80	17,100	Damaged fins.
E1-2158	Inert	29.1	80	79,500	Damaged fins.
E1-2163	Inert	29.2	80		Model failure.

* Electronics removed but antenna and plastic in boom untouched.

* The 7-0 projectile has recently attained an altitude of 300,000 feet.

did not provide good radar targets.* The two telemetry payload projectiles disintegrated during launch.

4. STATUS AND PLANS

The status of the 7-inch system, after this initial series of tests, can be summarized as follows:

a. The projectiles - the integrity and performance of the 7-0 probe appears adequate for the current state of development. The high performance prototype projectile exhibited problems with the fins. It is thought that these problems are not too serious, and should lend themselves to an early solution.
b. At this early stage of package tests there would appear to be no problems that can not be readily worked out.
c. The gun and mount system appear to be performing adequately.
d. The interior ballistic area is a major problem. The desired velocities are not being achieved at the computed pressures, and better performance is hindered by erratic pressure variations when large charges are used.

Current plans are first to solve the interior ballistic problems, second to determine the best designs for the three projectile series.

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**Damage during launch or ejection is suspected.*

responsible for many of the payloads. Credit is also due to the Ordnance Museums at APG and Fort Sill for releasing the only two existing T-76 mounts; Watervliet Arsenal for the design and manufacture of the tubes; and the Naval Propellant Plant, Macon, Georgia, for the design and manufacture of the pyrotechnic delays employed in the fuzing systems.

EUGENE D. BOYER LEONARD C. MacALLISTER

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The description of an upper atmosphere sounding system, based on a modified 175 mm gun, is given. The 175 mm gun tube is extended and smoothbored, and a T76 mount, modified to permit vertical fire is utilized. The gun is used to launch sub-caliber, fin-stabilized, center-saboted projectiles.

During initial tests, a prototype projectile with a payload volume of fifty cubic inches attained a maximum altitude of 260,000 feet. A smaller version of the projectile, with a potential payload volume of about fifteen cubic inches reached an altitude of 330,000 feet.

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